User's Manual

Model DTC-500A

Cryogenic Temperature Indicator/Controller

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Specifications, DTC-500A Cryogenic Temperature Controller

Input:

Temperature Range: 1.4 to 380K with Lake Shore DT-500 Series Sensors (0 to 3.0 volts for other sensors).

Recommended Sensors: DT-500 Series Silicon Diode Sensors (order separately). Calibration required over appropriate temperature range to provide V vs T data.

Sensor Input: Dual-sensor input. 4-terminal input for each sensor. Can be connected in 2-wire configuration. Sensor A position is used for automatic control mode. Sensor A or B positions are used in manual mode for temperature readout or manual control.

Sensor Excitation: 10 microampere current source.

Temperature Control:

Set-Point: Internally selected via 5 front-panel digital thumbwheel switches from 0.0000 to 2.9999 volts. Externally selectable via either resistance (0 to 1000 ohms) or voltage (0 to -3 volts). Optional BCD control with DTC-BCD Interface.

Set-Point Resolution: 100μV.

Typical Controllability: ±0.0005K for temperatures from 1.4 to 28K, ±0.005K at higher temperatures in a properly designed system.

Control Modes: Automatic: Proportional (gain), integral (reset), and derivative (rate). Set from front panel controls. Manual: 0 to 100% of full output can be set from front panel.

Heater Output: 0-25 watts into 25 ohm load. Heater current range can be limited at 10mA, 30mA, 100mA, 300mA, and 1A (approximate decade power increments).

Temperature Readout:

Method: Sensor voltage is nulled against set-point voltage using front-panel thumbwheels in MANUAL mode. Temperature is determined from V vs. T tables (requires sensor calibrated over appropriate temperature range).

Accuracy: ±100 microvolts ±calibration error of Sensor.

General:

Remote Set-point Input: 7-pin rear panel connector or optional BCD interface connector.

Dimensions, Weight: 432mm wide x 146mm high x 330mm deep (17 in x 5¾ in x 13 in). Style L, full-rack package. Net weight 8.2 kg (18 lbs).

Power: 105-125 or 210-250 VAC (switch selected), 50 or 60Hz, 65 watts.

Accessories Supplied: Mating connectors for sensor and remote inputs, instruction manual.

Options and Accessories Available:

Model DTC-BCD Interface. Allows remote digital control of set-point and provides BCD output of Sensor voltage divided by two.

Model SW-10A. 10-Sensor Selector Switch. Pushbutton selection of any one of up to 10 sensors. Dimensions: 216mm wide x 102mm high x 330mm deep (8½ in x 4 x 13 in). Style L half-rack package .

Model RM-3H. Rack mount kit to mount either one or two SW-10A in standard 3½" rack space .

Model RM-5F. Rack ears with handles to mount DTC-500A in standard 5¼" rack space .

Model DT-500 Silicon Diode Sensors. (Refer to Lake Shore Series DT-500 Technical Data for complete list).

DT-500K or DT-500KL
DT-500K-TO5 or DT-500KL-TO5
DT-500P-GR
DT-500P or DT-500P-GR MINI
DT-500FP
DT-500-CU-36

Sensor Calibrations. (Other ranges also available).

Type	Range-K
1.4B	1.4-40
1.4F	1.4-300
1.4G	1.4-380
4B	4.0-40
4F	4.0-300
4G	4.0-380

Expanded Calibration Printout. (Interpolated data at equal intervals over calibration range).

First 500 data points
Each additional 1000 data points

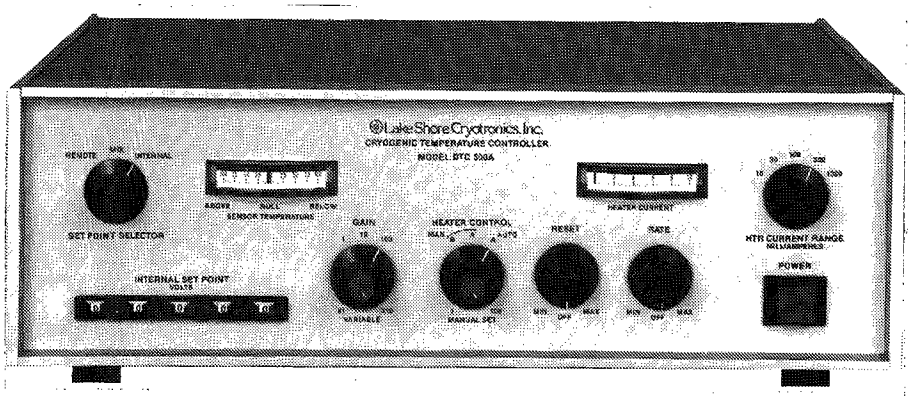


Figure 1.1 Model DTC-500A Cryogenic Temperature Indicator/Controller

SECTION I

General Information

1.1 Introduction

This section contains a description of the Model DTC-500A Cryogenic Temperature Controller, its applications, general specifications, major assemblies supplied and accessory equipment available.

1.2 Description and Applications

The Model DTC-500A Cryogenic Temperature Controller is housed in an aluminum case and is rack mountable with the RM-5H rack mount kit in a standard 19" relay panel. All connections are at the rear of the case with all normal operating controls on the front panel. The instrument is line operated from either 115 volt or 230 volt mains, 50 or 60 Hertz.

The controller is designed to accept a voltage signal from a temperature sensitive transducer (generally a DT-500 or TG-100 Series Diode which is not supplied), compare this signal with an internal set point voltage, amplify and process their difference (error signal), and drive an external heating element. An internal precision 10 microampere constant current source is provided to excite the temperature transducer.

The error processing section of the controller is of the proportional plus integral and differential mode design. Generous amplifier gain ranges have been provided to affect rapid closed loop response times, low steady state temperature offsets and to insure system stability over a wide range of thermal system parameters.

The output power amplifier is capable of supplying up to 25 watts of heater power. In view of the high cost of some cryogenic fluids such as helium, cost consciousness suggests that cryostat design and operating strategies be planned to limit heater power requirements to substantially less than twenty-five watts.

The principal intended application of the DTC-500A Controller is as a constant temperature regulator for laboratory size cryostats. Its basic design, however, enables it to be used as a general purpose controller for sensors whose outputs range between 0 and 3.0 volts and whose incremental sensitivities are in the range of tenths of millivolts or greater.

In addition to its use as a closed loop automatic temperature controller, the Model DTC-500 A Controller may be used as a precision thermometer. By adjusting the set point voltage so that the error signal(as indicated by the null meter) is zero, the output voltage of the temperature sensor is accurately obtained. Reference to a voltage versus temperature calibration curve for the transducer in use will then give its temperature.

1.3 General Specifications

The following specifications for the DTC-500 A Controller are applicable when used with the TG-100 or DT-500 full range temperature sensitive diodes.

General:

Controller Range	• 0.0001 volt to 2.9999 volts 1 K to 400 K for DT-500 series diodes
Heater Output	• 25 watts maximum
Sensor	• Models DT-500 or TG-100, temperature sensitive diodes, single-ended or floating models
Sensor Input	• Four terminal connection, constant current, potentiometric
Sensor Current	• 10 microamperes
Input Line Voltage	• 115V or 230V, 50-60 Hz
Power Consumption	• 65 watts
Circuit Design	• Solid State
Weight	• 8.2kg (18 lbs.)
Dimensions	• 5¼" high, 17" wide, 13" deep,
Sensitivity	• ∿4 Amp/millivolt into 25 Ω resistor at maximum setting

Temperature Control:

Set Points	• Internal, 0 to 3.0 volts via 5 digital thumbwheels. Remote, Analog - 0 to -3.0 volts; Digital - (optional) parallel BCD
Control Accuracy	• ±0.0005 K, 1 to 28 K ±0.005 K, 28 to 400 K { in a properly designed system for DT-500 series diodes
Setpoint Repeatability	• ±100 microvolts
Control Modes	• Proportional (gain), integral reset and derivative rate
Manual Control	• 0 to 100% of full output
Automatic Reset	• 1 to 100 second variable time constant, or off
Rate	• 1 to 100 second variable time constant, or off

Manual Output Control Range	• Potentiometer control, 0 to full scale of current setting
Full Scale Heater Current Ranges	• 10mA, 30mA, 100mA, 300mA, 1A
Heater Resistance	• 25 Ω for maximum power
Maximum Power Output Ranges	• 2.5×10^{-3} to 25 watts in multiples of 10
Controller Proportional Gain	• 4 Amp/mV in automatic mode (nominal)

Temperature Readout:

(Two sensor connections, front panel selectable between control sensor and temperature sensing only sensor)

Accuracy	• 100 microvolts calibration error of sensor and calibration error of full scale set point
Excitation Current	• 10 microamperes ±0.02%
Excitation Current Regulation	• 0.02%
Sensor Calibration Chart	• Must be supplied by manufacturer of sensor in use.

1.4 Major Assemblies Supplied

The Model DTC-500A Cryogenic Temperature Controller includes as standard equipment, in addition to the controller proper, the following additional components:

A. 1 - Operating and Service Manual

B. 2 - Five pin plugs for temperature sensor cables

C. 1 - Seven pin plug for remote set point cable

Temperature sensitive diodes are not supplied as part of the DTC-500A Controller.

1.5 Accessory Equipment and Custom Options Available

The following accessory equipment and custom options are available from the factory. Items marked with an asterisk (*) are of a custom nature. The customer should discuss these items with a factory representative before ordering.

A. Extra 5 and 7 pin connectors

B. Multisensor selector panel. (Special low thermal offset switch and cabling for selecting among multiple sensors.)*

C. Custom modification of sensor current supply value.*

D. DT-500 Silicon Temperature Sensitive Diode or TG-100 Gallium Arsenide (uncalibrated). (See data sheets at end of this manual for nominal operating characteristics and case styles available).

E. DT-500 Silicon Temperature Sensitive Diode or TG-100 Gallium Arsenide (calibrated). Standards laboratory calibration service for correlating diode output voltage with diode temperature. See sensor data sheet for additional information. Also see Cryogenic Calibration Service data sheet.

F. Power boosters for heater power requirements in excess of twenty-five watts, or other than twenty-five ohm heater resistance.

G. BCD Input/Output (Optional). Include parallel BCD input of set point and a parallel BCD output of sensor voltage.

H. Model RM-5F rack ears with handles to mount DTC-500A in standard 5¼" high, 19" wide rack space.

SECTION II

Installation

2.1 Introduction

This section contains information and instructions necessary for the installation and shipping of the Model DTC-500A Cryogenic Temperature Controller. Included are initial inspection instructions, power and grounding requirements, installation information and instructions for repackaging for shipment.

2.2 Initial Inspection

This instrument was electrically and mechanically inspected prior to shipment. It should be free from mechanical damages, and in perfect working order upon receipt. To confirm this, the instrument should be inspected visually for obvious damage upon receipt and tested electrically by use to detect any concealed damage. Be sure to inventory all components supplied before discarding any shipping materials. If there is damage to the instrument in transit, be sure to file appropriate claims with the carrier, and/or insurance company. Please advise the company of such filings. In case of parts shortages, please advise the company. The standard Lake Shore Cryotronics warranty is given on the first page of this manual.

2.3 Power Requirements

Before connecting the power cable to the line, ascertain that the line voltage selector switch (115V or 230V) is in the appropriate position for the line voltage to be used. Examine the power line fuse, FU1, (Key No. 14, Page 12) to insure that it is appropriate for the line voltage. (115V = 0.75 Amp, 230V = 0.40 Amp). Nominal permissible line voltage fluctuation is ±10% at 50 to 60 Hz.

CAUTION: Disconnect line cord before inspecting or changing line fuse.

2.4 Grounding Requirements

To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends and some local codes require instrument panels and cabinets to be grounded. This instrument is equipped with a three-conductor power cable, which, when plugged into an appropriate receptacle, grounds the instrument.

2.5 Installation

The DTC-500A Controller is all solid state and does not generate significant heat except in the 1 amp scale. It may therefore be rack mounted in close proximity to other equipment in dead air spaces. However, the heat from such adjacent equipment should not subject the DTC-500A Controller to an ambient temperature in excess of 50°C (122°F). As with any precision instrument, it should not be subjected to the shock and vibrations which usually accompany high vacuum pumping systems.

The recommended cable diagrams for the sensor diode and heater element are given in Figure 2.1 (a) and (b). The use of a four wire diode connection is highly recommended to avoid introducing lead IR drops in the voltage sensing pair which is translated into a temperature measurement error. The indicated shielding connections are the recommended standard practice to avoid ground loops. The alternate wiring scheme shown in Fig. 2.1 (c) may be used for the diode, in less critical applications where control is important, but small temperature readout errors can be tolerated.

The heating element should be floated to preclude the possibility of any of the heater current being conducted into the diode sensor leads. Electrical feedback in addition to the desired thermal feedback, may cause oscillations and certainly erroneous temperature readings.

Inspect the heater element fuse FU2, (Key No. 16, Pg. 12) for proper value. (3 AG, 1.0A, Fast Blow, or smaller current rating if desired.) This fuse protects the output amplifier from damage in case of heater element shorting. Use of a larger fuse may cause damage to the instrument and invalidates the instrument warranty.

2.6 Repackaging for Shipment

Before returning an instrument to the factory for repair, please discuss the malfunction with a factory representative. He may be able to suggest several field tests which will preclude returning a satisfactory instrument to the factory when the malfunction is elsewhere. If it is indicated that the fault is in the instrument after these tests, the representative will send shipping instructions and labels for returning it.

When returning an instrument, please attach a tag securely to the instrument itself (not on the shipping carton) clearly stating:

A. Owner and address

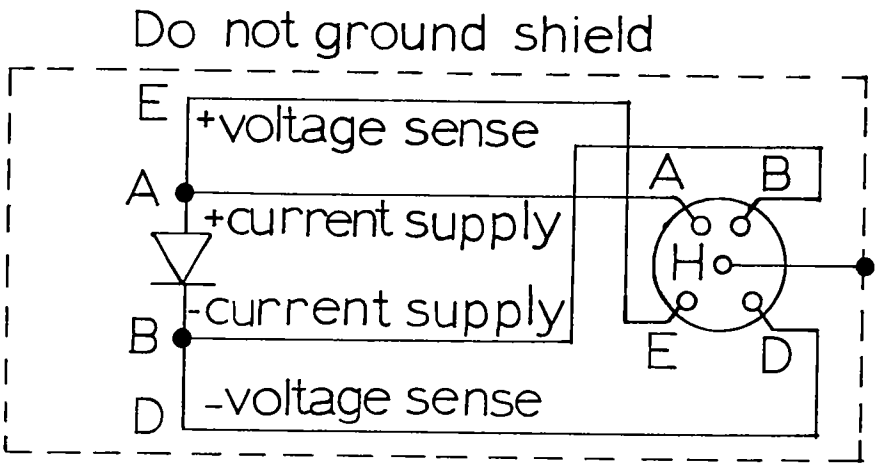
B. Instrument Model and Serial Number

C. Malfunction symptoms

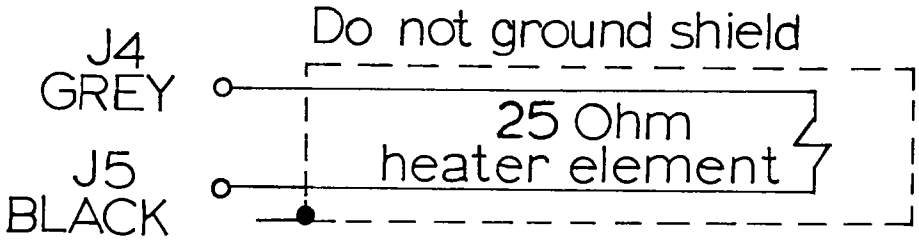
D. Description of external connections and cryostats.

If the original carton is available, repack the instrument in plastic bag, place in carton using original spacers to protect protruding controls, and close carton. Seal lid with paper or nylon tape. Affix mailing labels and "FRAGILE" warnings.

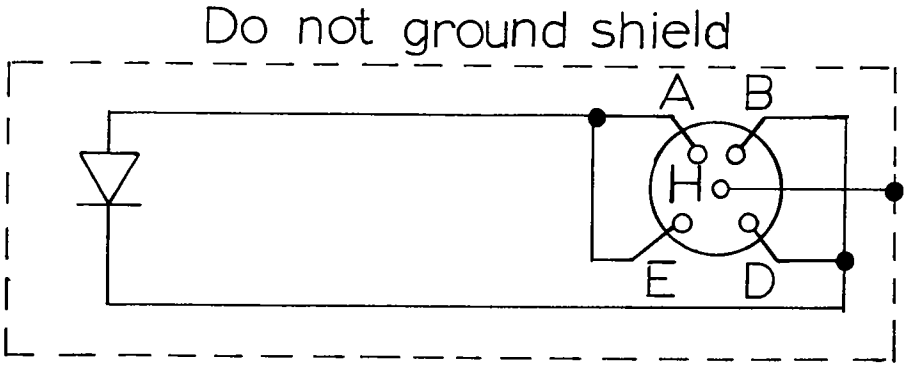
If the original carton is not available, wrap the instrument in protective plastic wrapping material before placing in an inner container. Place shock absorbing material around all sides of the instrument to prevent damage to protruding controls. Place the inner container in a second heavy carton and seal with tape. Affix mailing labels and "FRAGILE" warnings.



(A) RECOMMENDED SENSOR CABLE



(B) RECOMMENDED HEATER CABLE



(C) ALTERNATE SENSOR CABLE

FIGURE 2.1 SENSOR AND HEATER CABLES

SECTION III

Operating Instructions

3.1 Introduction

This section contains a description of the operating controls, their adjustment under normal operating conditions, typical controller applications and suggested cryostat adjustment techniques. These instructions are predicated upon the instrument having been installed as outlined in Section II. The diode polarity as shown in Fig. 2.1(a) in particular must be correct. A calibrated diode is assumed to be connected, as shown in Fig. 2.1(a), to the "Sensor A" receptacle and a 25 ohm heating element is assumed to be connected to the "Heater" terminals as shown in Fig. 2.1(b).

3.2 Controls, Indicators and Connectors

The operating controls, indicators and connectors on the instrument's front and rear panels are shown in Fig. 3.1 and 3.2. The numbers with leaders to various controls in the figures are keyed to the entries in Table 3.1.

Table 3.1 - Entry Number Correlation

No. Key	Name	Function
1	SET POINT - VOLTS 0 - 2.9999	Digital set point of sensor voltage
2	GAIN	Gain Multiplier, X1, X10, X100
3	GAIN	Variable gain 1-10. Together with gain multiplier, allows adjustment of overall controller gain over 1000 to 1 range
4	MAN. B, MAN. A, AUTO A	Mode selector switch: AUTO A uses sensor A to automatically control temperature. MAN. A disengages automatic control feature but permits readout of sensor A voltage. MAN. B permits readout of sensor B voltage.
5	MAN. SET	When mode selector switch (4) is in either MAN. A or MAN. B position, the MAN. SET potentiometer permits the user to manually adjust the current to the heater element. (Caution: High current settings will quickly boil away cryogenic fluids).
6	AUTO-RESET OFF, MIN. - MAX.	Adjusts auto-reset time constant of integrator. (See Fig. 3.3) Effectively determines times constant of integrator between 100 and 1 seconds, "MIN." and "MAX." respectively, or "OFF".

No. Key	Name	Function
7	RATE OFF, MIN.-MAX.	Adjusts Auto-rate time constant of differentiator. Effectively determines time constant of differentiator between 1 and 100 seconds, "MIN." and "MAX." respectively, or "OFF".
8	POWER	A. C. line switch (ON/OFF) and pilot light.
9	HTR CURRENT RANGE MILLIAMPERES	Switch selected current selector. Use of a low setting will avoid inadvertent boil-off in setting up system, and/or system oscillations
10	HEATER CURRENT	Monitors heater element current. Full scale deflection corresponds to MAX. HEATER - AMP. switch (9) setting.
11	NULL	Indicates the difference between the set point voltage and the sensor output voltage. Meter is non-linear for large errors of either sign. See page 23 and 24 for discussion.
12	INT. - REM.	Selects between internal set point and remote set point. The center position allows a mixture of both set points. Front panel set point inoperative with switch in "REMOTE" position.
13	115-230 VAC	A. C. line voltage selector slide switch (50-60 Hz).
14	0.75-0.4 AMP.	A. C. line fuse (FU1). See para. 2.3. 115 VAC-0.75 AMP., 230 VAC - 0.4 AMP.
15	NO LABEL	A. C. line cord
16	1.0A, F.B.	Heater element line fuse, 1 AMP., Fast Blow
17	SENSOR A, J1	Sensor A cable receptacle. (Five pin, Amphenol type 126-217 Plug)
18	SENSOR B, J2	Sensor B cable receptacle. (Five pin, Amphenol type 126-217 Plug)
19	REMOTE INPUT, J3	Remote set point either by means of 0 to -3 volt signal or a potentiometer. (Amphenol 126-195 Plug).
20	J4	40 pin connector for "REMOTE" BCD in/out option
21	HEATER	Heater element lead terminals (Grey is the high side and Black is the low side).

No. Key	Name	Function
22	GROUND	Chassis ground terminal
23	NO LABEL	Heat sink for output transistors

3.3 Initial Checks

Initial checks, calibration checks, and servicing procedures are described in Section V, MAINTENANCE.

3.4 Temperature Readout Mode

To use the DTC-500A as a cryogenic thermometer to measure the temperature of a calibrated diode connected to SENSOR A terminals, initially position switches and controls as follows:

A. Temperature set point switch (Key No. 12) to internal, "INT.".

B. Mode switch (Key No. 4) to "MAN. A".

C. "MANUAL SET" (Key No. 5) to one.

D. HTR CURRENT RANGE (Key No. 9) to 10.

E. "GAIN" (Key No. 2 and 3) to minimum setting.

F. "RESET" (Key No. 6) to off.

G. "RATE" (Key No. 7) to off.

H. "POWER" switch (Key No. 8) to on.

The null meter will probably deflect off scale (either left or right) when the power switch is turned on. If the deflection is to the right, the set point voltage is less than the sensor voltage. If the deflection is to the left, the set point voltage is greater than the sensor voltage. In other words, in order to null the meter, turn the set point in the direction that you wish the needle to move.

If the null meter will not null regardless of the set point voltage check to make sure that the printed circuit card located behind the thumbwheel digits has not worked loose from its proper position during shipping. This can be easily observed by removal of the top cover.

Adjust the set point voltage until the "NULL" meter is centered while increasing the "GAIN" toward maximum. Increasing the voltage will move the meter pointer to the left; decreasing the set point voltage will deflect the meter pointer to the right. After centering the meter, the set point voltage can be read directly to 100 μvolts. A table of relative sensitivity for the null meter as a function of gain setting is given on page 26.

After determining the set point voltage, refer to the diode calibration chart to ascertain the diode temperature.

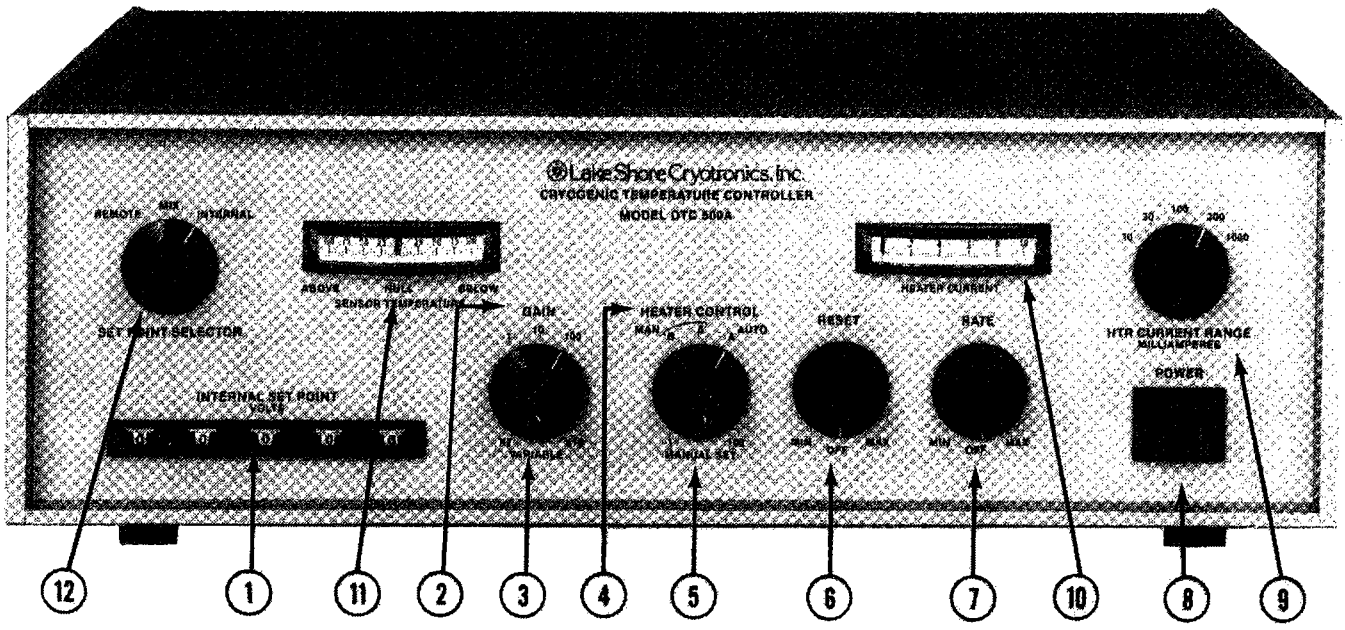


FIGURE 3.1 DTC-500A Cryogenic Temperature Controller Front Panel

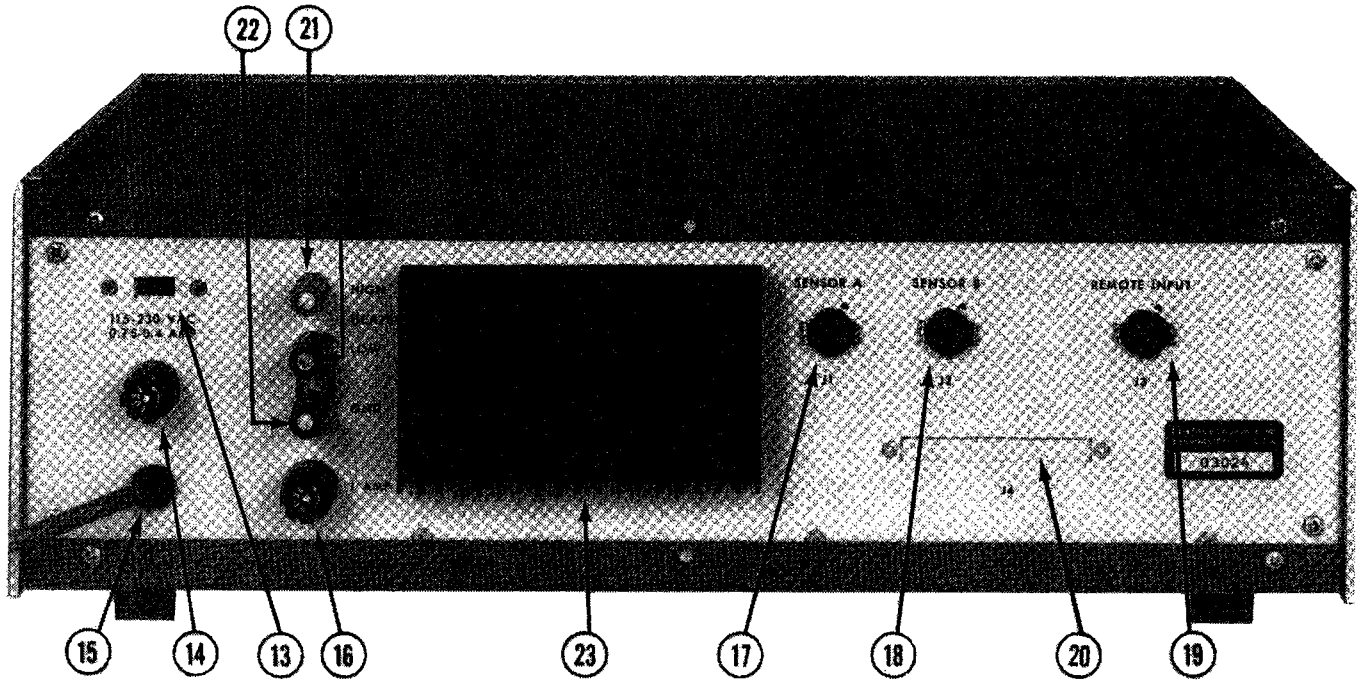


FIGURE 3.2 DTC-500A Cryogenic Temperature Controller Rear Panel

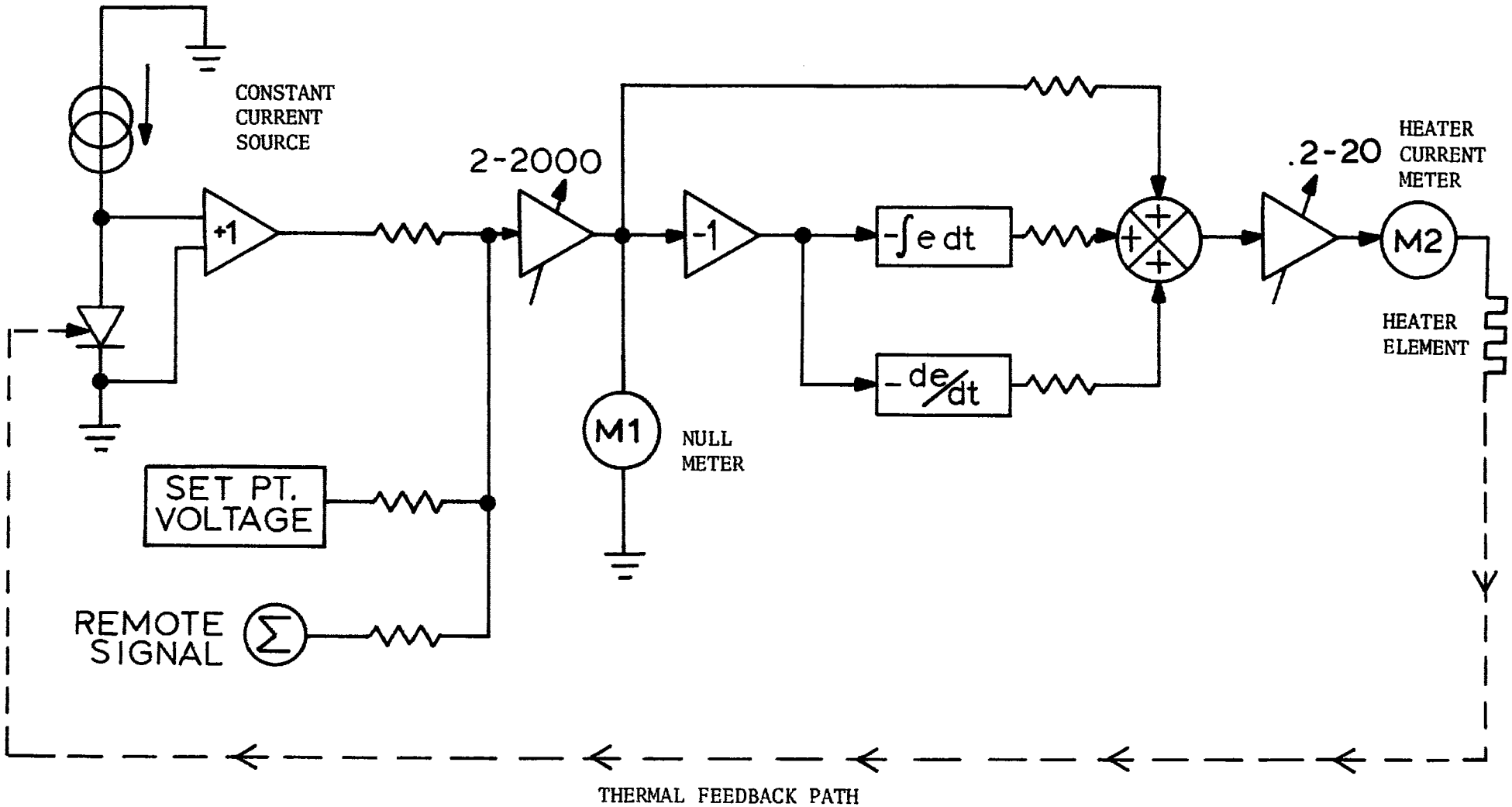


FIGURE 3.3-BLOCK DIAGRAM, DTC-500A TEMPERATURE CONTROLLER

3.5 Constant Temperature Control Mode

Assume that a calibrated diode is in use as described in paragraph 3.4. To maintain a constant temperature, determine the corresponding set point voltage from the diode calibration chart. Set this voltage on the "SET POINT" switches.

Position controls as indicated below:

A. Temperature set point switch (Key No. 12) to "INTERNAL".

B. Mode switch (Key No. 4) to "AUTO A.".

C. "MANUAL SET" (Key No. 5) to one.

D. HTR CURRENT RANGE (Key No. 9) to 1000 Milliamperes.

E. "GAIN" (Keys No. 2 and 3) to minimum settings.

F. "RESET" (Key No. 6) to off.

G. "RATE" (Key No. 7) to off.

H. "INTERNAL SET POINT-VOLTS" switch (Key No. 1) to voltage corresponding to desired temperature.

I. "POWER" switch (Key No. 8) to on.

If the block or sample holder whose temperature is to be controlled is colder than the set point temperature, the sensor diode voltage will be high and the null meter will deflect to the right: Slowly increase the "GAIN" setting (Keys No. 2 and 3). The "HEATER CURRENT" meter should show an immediate up scale deflection proportional to the "GAIN" setting. The "NULL" meter should start to come off its full right deflection position as the gain is increased. As the sample holder temperature approaches the set point temperature, the NULL meter will approach center scale and the "HEATER CURRENT" meter will assume a steady value even with a further increase in the gain setting. Continue to increase the gain until an incremental change in gain produces a negligible reduction in the null error, but not so high as to produce oscillations.

To further reduce the null error, rotate the "AUTO RESET" gain control (Key No. 6) out of the detent (off) position in the clockwise direction. As the control is advanced, the null meter should approach the center position with unobservable error. Leave the "AUTO RESET" vernier in the position required to reduce the null error to zero, but below any level which induces oscillations.

After achieving a stable operating point, reduce the HTR CURRENT RANGE (Key No. 9) to a lower setting. As lower settings are dialed in the percent (%) of maximum, heater current being used should increase. The optimum area for control can be obtained by keeping the meter pointer between 0.2 and 0.7 on the meter face.

Abruptly increase the set point voltage by ten millivolts. The sensor voltage now represents a temperature warmer than that represented by the set point voltage. The NULL meter should deflect to the left and the HEATER CURRENT should go to zero immediately. As the sample holder cools, the NULL METER pointer should return toward zero.

As the NULL METER pointer approaches zero, the HEATER CURRENT will increase from zero to the new steady state value required to maintain the sample at the lower temperature requested. The NULL METER should read zero as the HEATER CURRENT stabilizes at its new value.

Now abruptly decrease the set point vernier control by ten millivolts. The sensor voltage now represents a temperature colder than that represented by the set point voltage. The NULL meter should deflect to the right and the HEATER CURRENT meter should deflect toward full scale. As the sample holder heats, the NULL meter pointer will tend to zero and the HEATER CURRENT meter reading will decrease toward its new steady state value. As the NULL meter centers, the HEATER CURRENT should stabilize at the new constant value required to maintain the desired temperature.

A sketch of the temperature versus time pattern described above is given in Figure 3.4. Observe that there is no temperature overshoot or oscillation when the "GAIN" and "AUTO RESET" controls are properly adjusted. (This statement presupposes that the sample holder, heater, and sensor may be accurately modeled as a simple R-C type time constant thermal circuit.)

If oscillation or overshoot are observed when changing the set point voltage in small increments, reduce the GAIN and increase the AUTO RESET time constant (rotate CCW) settings until oscillations are no longer observed and/or adjust the HTR CURRENT RANGE (Key No. 9) to a lower setting.

Normally at cryogenic temperatures, the above adjustments will result in a stable system with good transient response due to the short time constants encountered at these temperatures. For these constants, the rate switch should remain in an off position. If, however, the transient response of the system must be improved, this can be done by the addition of rate (or derivative) to the control functions.

Physically, the effect can be described as introducing anticipation into the system. The system reacts not only to the magnitude and integral (RESET) of the error, but also its probable value in the future. If the error is changing rapidly, then the controller responds faster. The net result is to speed up the response of the system.

To increase system response (if needed) take the "RATE" control (Key No. 7) out of the detent (off) position in the clockwise direction. For various settings of the control, observe the transient response to a change in set point. Too short a time constant may result in oscillation and an unstable system. A change in gain may be necessary to eliminate oscillation or overshoot.

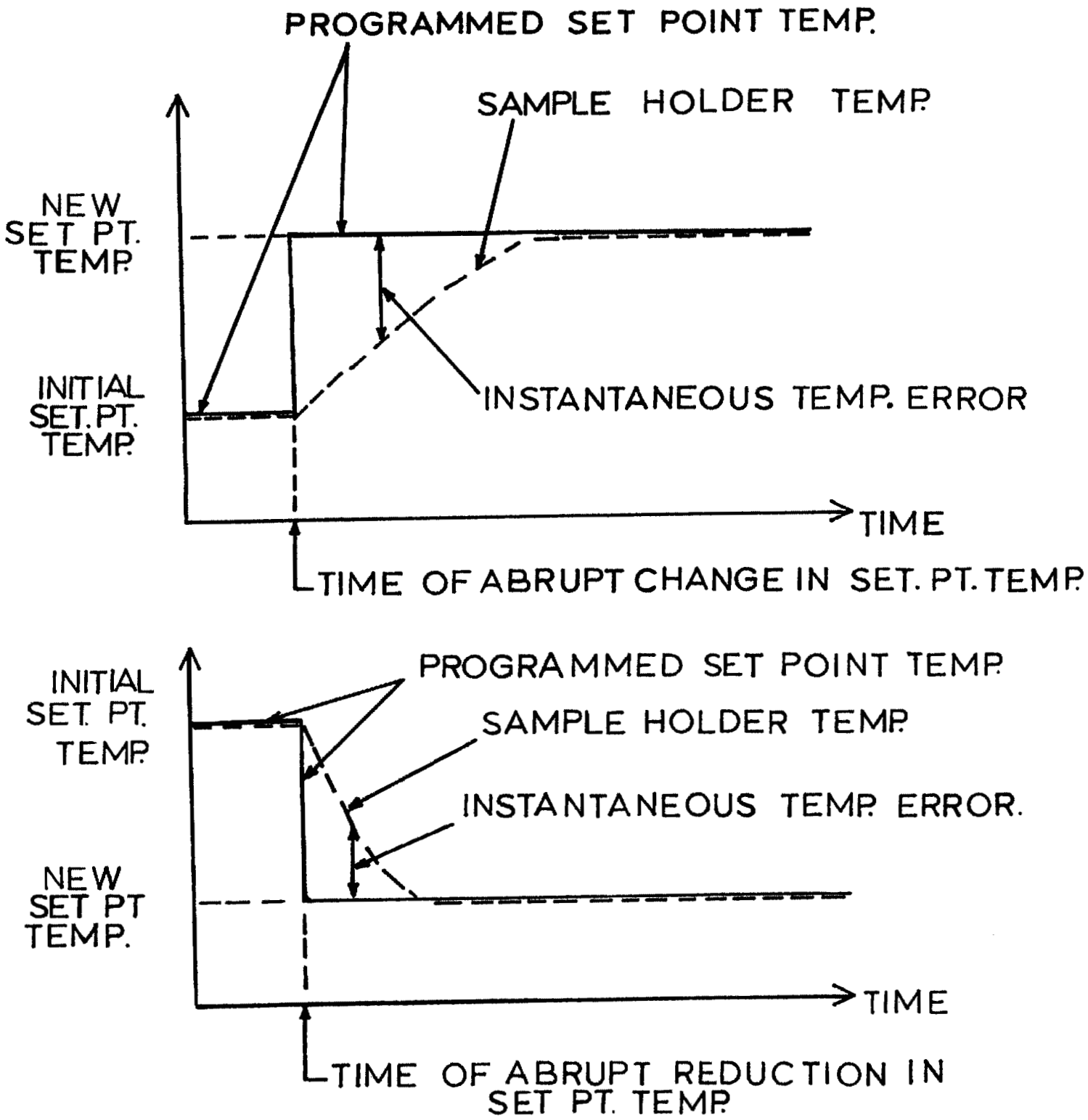


Figure 3.4 Temperature versus Time Characteristics of Controller

3.6 Manual Reset Heating Mode

By placing the mode selector switch (Key No. 4) in either MAN. A or MAN B, a manually settable constant current may be supplied to the heater element. The magnitude of the current is determined by the setting of the MAN RESET potentiometer (Key No. 5) and the HTR CURRENT RANGE (Key No. 9). The current supplied to the heater is indicated on the HEATER CURRENT meter. The full scale reading of the meter corresponds to the HTR CURRENT RANGE switch setting. MAN RESET allows the user to hold a temperature for a short period of time in an open loop condition while he uses the null meter and the digital set point to read a second sensor. This is accomplished by adjusting the output current (Key No. 5) such that the heater current (Key No. 10) does not vary when switched from Auto A to MAN. A or MAN. B (Key No. 4).

3.7 Temperature Readout Mode (Sensor B)

In some applications, the temperature is controlled (or regulated) at one physical location while it is desired to measure the temperature at a second location. This requires two sensors, "Sensor A" located at the temperature control point and "Sensor B" at the second point where only the temperature is to be measured. Sensor B must be calibrated.

3.8 Current Source Modification

The current source within the DTC-500A is floating and presently excites either Sensor A or Sensor B, depending on the switch position of the mode selector switch (Key No. 4). A simple wiring change can be made so that both Sensors A and B are excited simultaneously if either or both sensors are electrically isolated from a common ground. With the instrument lid removed, unsolder the wire to Pin A, Sensor B connector, and resolder to Pin A, Sensor A connector, unsolder the wire to Pin B, Sensor A, and resolder to Pin B, Sensor B connector (now two wires on this terminal). Now solder a wire between Pin B, Sensor A connector, and Pin A, Sensor B connector. The two sensors are now connected in series. If you wish to use only Sensor A, make up a shorting plug for Sensor B terminal that shorts Pin A to Pin B.

For some applications, a constant current other than 10 μA is desired. This constant current is programmed by means of the following formula: I 4.99/R7 with R5 being a trim for this current. For 10 μA, R7 is 499K; for 100 μA, R7 must be 49.9K. The current source can be programmed between 1 μA and 1 mA, if desired. The compliance voltage is slightly less than 5 volts.

3.9 Remote Temperature Programming

Three types of remote programming are acceptable by the DTC-500A. They are:

A. An analog signal from 0 to -3 volts (standard)

B. An external resistance divider (standard)

C. A parallel BCD set point including an A/D converter with parallel BCD output of one half of the sensor voltage (option).

Remote temperature control can be achieved by applying either A or B of the above signals and switching the "SET POINT" to the "REMOTE" position or the center "MIX" position. In the "MIX" position, the remote signal and the internal set point are added directly. The BCD set point replaces the front panel set point in the "INTERNAL" position.

3.9.1 Remote Voltage Programming

To apply a remote voltage signal to the DTC-500A, connect a 0 to -3 volt signal between Pin E and Pin A (the analog ground) of the REMOTE INPUT connector J3 on the rear panel of the unit.

3.9.2 Remote Resistance Divider Programming

Remote temperature control can also be achieved by connecting an external resistance divider to J3 and switching the "SET POINT" to the "REMOTE" position or the center "MIX" position. Pin D of J3 is a precision regulator of 6.9 volts ±5%. To insure maximum accuracy, the total resistance between pins E-D of J3 should be greater than 10,000 ohms. Since the signal desired is less than 3 volts, a dropping resistor, R_d, must be used to limit the voltage across the variable resistor to less than 3 volts. The remote set point diagram is shown in Figure 3.5.

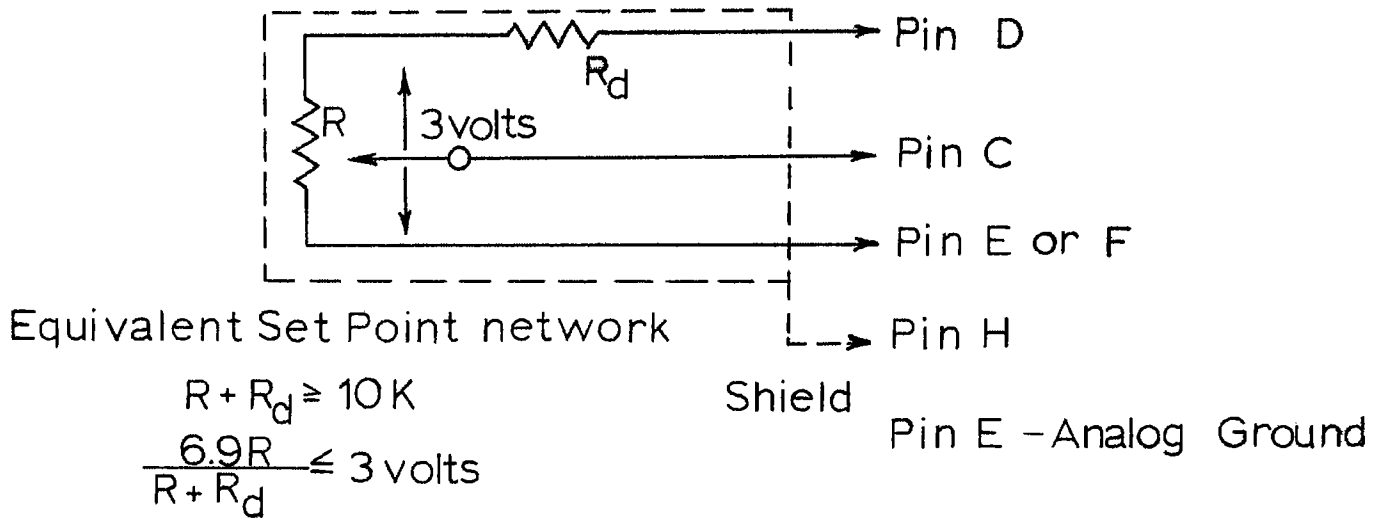


Figure 3.5-Remote Temperature Programming

A number of external temperature programming networks are shown in Figure 3.6.

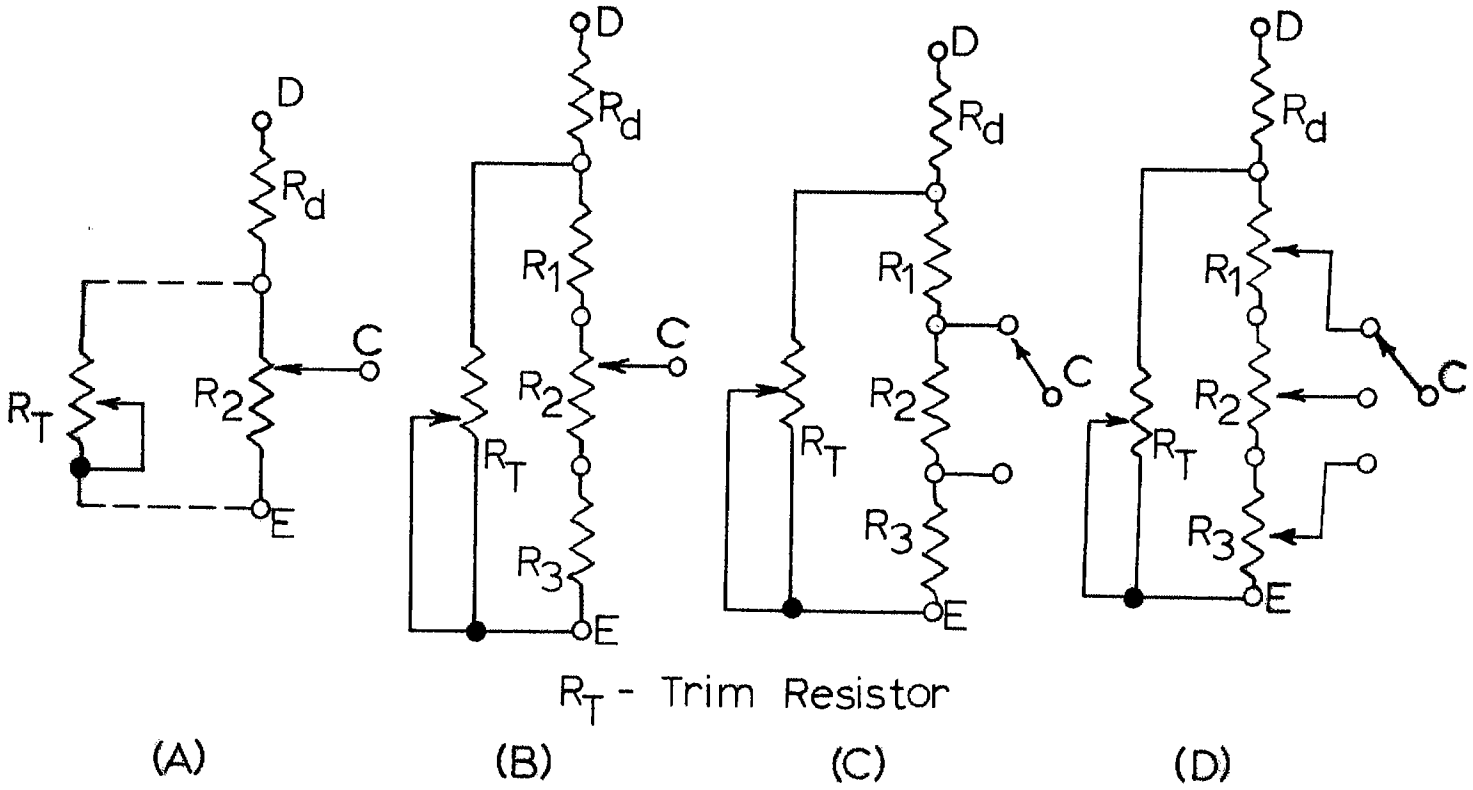


Figure 3.6-Programming Networks

The following is a suggested procedure for designing external temperature set point control circuitry:

A. Determine the range of desired temperature control voltage.

B. Choose the most suitable control circuit for your application:

   a) Temperature control range - 100%

   b) Limited temperature control range

   c) Fixed temperature set points selected in steps

   d) Most flexible arrangement allowing for selected steps and continuously variable temperature set points.

   Additional variations of the above may be tailored to fit the intended application.

C. To insure that the total resistance between pins E & D of the external programming voltage divider be of the correct value to develop a drop of 3 volts across the programming resistor, it is suggested that the divider calculation be based on more than 1600 ohms per 1 volt and a shunting resistor (R_T in Fig. 3.6) used for precision trimming to 3 volts.

   The 3.0 volts can be measured with a precision floating voltmeter, with the sensor circuit open, i.e., sensor plugs disconnected, or calibrated with the DTC-500A internal set point volts switch as follows:

   a) Connect a precision known resistor R (any value between 50K-250K) to the pins AE and BD of the Sensor A input plug J1 (Amphenol type 126-217 or equivalent) in place of the sensor as shown in Fig. 3.7, and turn the sensor selector switch on the front panel to Manual A position.

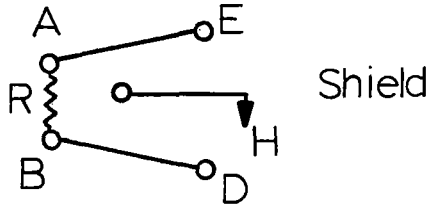


Figure 3.7-Programming Voltage, J1

The voltage drop across resistor R is equal to 10×10^{-6} (amperes) x R (ohms) volts, thus a 100 K ohm resistance would result in a 1 volt drop. With the "TEMPERATURE SET POINT" switch in "INTERNAL" position, the null meter will indicate zero error when the internal temperature set point switch on the front panel is at 1.000 volts. Increase the

gain to maximum and adjust the internal set point, if necessary, for the null meter to indicate zero. Move the reference set point switch to "EXTERNAL" position and adjust trim resistor R_T on the external set point programming instrument so that the null meter reads zero.

The external programming network is now matched to the internal reference source. Although one point calibration as described above is sufficient, it may be desirable to check several points. In that case, a precision rheostat may be used for R at the sensor input connector. However, the leads as well as the divider resistor should be shielded, and the shields connected to pin H of the sensor A input connector (J_1). Similarly, the leads and box housing the externally programmable temperature resistance network should be shielded through pin H of external set point plug (J_3).

3.9.3 Remote Parallel BCD Input/Output Option

The remote programming option consists of a TTL parallel 18-bit input of set point voltage and a TTL parallel 17-bit output of one-half of the sensor voltage. It is assumed that the sensor voltage output can be multiplied by two within the computer. The cable pin-out connectors are indicated in Tables 3.2 and 3.3.

Both the internal and external BCD input of the set point is accomplished either in the "INTERNAL" or "MIX" position by setting connector J_4 pin-38 high (+5V) for external BCD or low (0 V) for internal BCD . Both internal and external BCD set points are disabled in the "REMOTE" position. Note that in the "MIX" position either BCD set point can be combined with an external signal from connector J3.

The BCD output of one-half of the sensor voltage is present in all modes, "INTERNAL", "MIX", and "REMOTE".

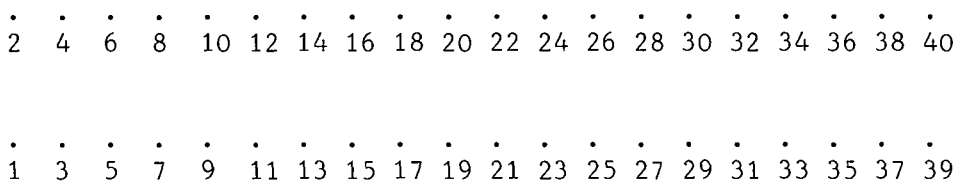
3.10 Grounding

The chassis is grounded by the 3 lead power cable to the electrical supply common ground. The common lead of the controller circuitry ("Lo" terminal of the heater output - Key 22, Fig. 3.2) can be externally connected to the chassis ground terminal. Although the grounding of the controller common is normal operation practice, the common "Lo" terminal may be disconnected from chassis ground if doing so helps to eliminate accidental ground loops within the system.

The effect of grounding may be observed by monitoring the a.c. signal present on the heater circuit. Choose the connection which reduces the a.c. signal to its lower value.

Table 3.2

PARALLEL BCD INPUT OF SET POINT

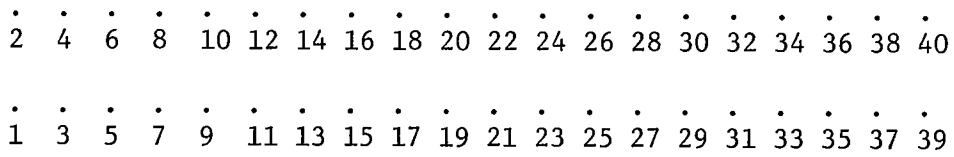


Pin	Function
J4 - 2	BCD .0008
J4 - 4	BCD .0002
J4 - 6	BCD .0004
J4 - 8	BCD .0001
J4 - 10	BCD .008
J4 - 12	BCD .002
J4 - 14	BCD .004
J4 - 16	BCD .001
J4 - 18	BCD .08
J4 - 20	BCD .02

Pin	Function
J4 - 22	BCD .04
J4 - 24	BCD .01
J4 - 26	BCD .8
J4 - 28	BCD .2
J4 - 30	BCD .4
J4 - 32	BCD .1
J4 - 34	BCD 2
J4 - 36	BCD 1
J4 - 38	If high (+5V) Select Remote Set Point
J4 - 40	

Table 3.3

PARALLEL BCD OUTPUT OF SENSOR VOLTAGE



Pin	Function
J4 - 1	BCD .0001
J4 - 3	BCD .0002
J4 - 5	BCD .0004
J4 - 7	BCD .0008
J4 - 9	BCD .001
J4 - 11	BCD .002
J4 - 13	BCD .004
J4 - 15	BCD .008
J4 - 17	BCD .01
J4 - 19	BCD .02

Pin	Function
J4 - 21	BCD .04
J4 - 23	BCD .08
J4 - 25	BCD .1
J4 - 27	BCD .2
J4 - 29	BCD .4
J4 - 31	BCD .8
J4 - 33	BCD 1.
J4 - 35	DATA VALID
J4 - 37	
J4 - 39	Common Ground

Note: BCD output is one-half of actual sensor voltage.

SECTION IV

Theory of Operation

4.1 Introduction

This section contains the theory of operation of the DTC-500A Controller and a functional characterization of the controller in Laplace transform notation to aid the thermal system designer in system stability analysis.

In some applications, it may be required for an experienced user to modify the gain, reset or rate range. The information given within this section should make these modifications straightforward.

4.2 General Description

Refer to Figure 3.3 and Figure 5.1 as an aid in the following discussion. A precision constant current source causes 10 microamperes of DC current to bias the control diode. The voltage developed across the control diode is fed through a buffer amplifier and this voltage generates a positive current through the 3 megohm resistor into the current summing amplifier.

The digital set point is converted to an analog voltage by the five digit D/A converter. The resulting voltage is negative and an appropriate resistance string is chosen so that its current into the summing amplifier just balances the sensor generated positive current. The result is zero current at the summing junction when the set point voltage is just equal to the sensor voltage.

Because a current summing operational amplifier is used, many signals can be mixed together. Therefore, the digital set point signal can be mixed with the remote signals described in Section 3.9. The gain of the controller is built into this summing operational amplifier. A simplified equivalent circuit of this amplifier is shown in Figure 4.2 The associated switching from sensor A to sensor B and the switching associated with the internal and remote switch are shown in Figure 4.1. From Figure 4.1, it can be seen that the error signal is a current which is amplified as a voltage by the variable gain operational amplifier U10 of Figure 4.2. The amplified error is displayed on the NULL meter and also applied through an inverter to (1) an integrator circuit (reset), (2) a bound or clamping circuit and (3) a differentiator circuit (rate).

The error signal, its integral and differential, are summed as current by the operational amplifier U12. This amplifier then drives the output power circuit. The current from the power amplifier is metered by the current meter. Changing the current range from 10mA to 1 Amp changes the voltage gain of the output stage from 0.2 to 20. Closed loop control action is achieved through the thermal path between the heater element and the temperature sensing diode.

4.3 Detailed Description

(a) Power Supplies

There are four regulated supply voltages within the DTC-500A. They are designated as P/S-1 through P/S 4 (Figure 5.1). P/S-1, consisting of a diode bridge and regulator U-18, supplies a regulated 15 volts and an unregulated 18 volts to the circuit comprising the constant current source. P/S-2 and P/S-3 consist of a diode bridge with regulators U17 and &16 which supply +15 volts and -15 volts respectively. P/S-4, consisting of a diode bridge and regulator U-15, supplies the +5 volts used for the BCD option only.

P/S-5 is an unregulated supply for the output power stage. The output voltage is 25 volts on the one ampere scale and approximately 7.5 volts for all lower current settings.

(b) Diode Constant Current Supply

A precision reference voltage is generated by an internally temperature stabilized precision voltage reference, U23. Resistors R3 thru R6 vary this voltage to match the voltage generated by feedback resistor R7. Resistor R7 has been selected to generate 4.99V across it when the output current is 10 microamperes. Op amp 419 drives an FET (U21) to generate a current flow through Pins A and B of the selected input sensor connector. This current is varied by trimpot R5.

The entire constant current supply system was designed to be fully floating so that the cathode of the sensor diode might be returned to common.

(c) Set Point Voltage

The digital set point consists of a digital-to-analog converter which is linear to approximately lppm. Its accuracy is obtained by a simple, symmetrical application of the mark: space ratio principle. A single up/down counter chain is used, which alternately counts down to zero and up to the maximum from the value to be converted. The first of these intervals is used for the 'mark'time, the second for the 'space' time; the sum of the two being independent of the input value. This circuit has a response time of approximately one second and is advantageous for setting up steady state voltages where a fast response to changes in input is not reuired. The circuit is described in detail in a paper by J.R. Stockton*.

(d) Input Internal-Remote Circuitry

Figure 4.1 shows part of the input circuitry for the DTC-500A.

* "A simple, highly linear mark:space ratio digital-to-analog converter." J.R. Stockton, J. of Physics E: Scientific Instruments, 1977, Vol. 10

The sensor select switch selects either sensor A or sensor B voltage leads as indicated as well as switching the current leads (not shown). Note that the negative voltage lead is grounded with the current source negative and positive leads floating. The sensor voltage goes through a buffer amplifier prior to being converted to a positive signal current by resistors R14 & R15. This buffered voltage is available to the user at terminal B of J3. R13 (110 ohms) is present so that inadvertant shorting of this output does not destroy the buffer amplifier.

The INT-REM switch selects between the internal set point and the external set points. In its center position, the internal set point and the remote set point signals (if present) are mixed. Do not use the mix position unless you intend to use both internal and remote signals, since the remote set point will tend to generate noise if no signal is present. In the remote position, the unused input should be grounded so as to eliminate potential sources of noise.

Note that all external signals must be negative as well as the internal set point. At null, the current from the sensor is just balanced by the negative current(s) from its set point(s) resulting in error signal which is dependent on the gain setting for no reset and zero for the normal operation when reset is engaged.

(e) Summing Variable Gain Amplifier

A simplified unit for the summing amplifier is shown in Figure 4.2. Capacitors C14 and C15 are present for high frequency stability. Since all input currents flow through equal resistors, an equivalent error voltage signal is $V_\epsilon = i_\epsilon$ R15, with R_g either ∞, 10K, or 1K. The gain of this amplifier varies from 2 to 2000 depending on the position of the variable gain potentimeter and gain multiplier switch.

Not shown in Figure 4.2 is the null resistor R-30 and the trim resistor R27. The trimming of this amplifier is described in Section 5.8. CR3 and CR4 are 6.8 volt zener diodes which are present to keep the amplifier out of saturation due to extraneous noise spikes (also not shown).

(f) Null Meter Circuit

Directly after the variable gain summing amplifier is the null meter circuit. The Null Meter is desensitized for large errors by placing two germanium diodes across its terminals. The result is a linear scale for error less than 50% of full deflection in either direction with high non-linearity for larger errors. Sensor-set point error in null can be related to gain settings by the following table for small errors:

Table 4.1

Translation of Null error versus set-point deviation as a function of gain:

Gain	Sensor Set-Point Error, mV/div.
1	70
5	36
10	7
50	3.1
100	.75
500	.35
1000	.08

(g) Automatic Reset Circuit, Bounding Circuit

The bound circuit and variable gain integrator are realized by operational amplifiers U11 and U13 respectively. A simplified equivalent circuit of the circuit is given in Figure 4.3.

Note, from Figure 5.1, that the amplified error signal (Vo) is inverted (Amplifier U11) prior to being integrated by this amplifier. Application of the principle that the summing junction currents must add to zero yields the overall transfer function of the stage.

The bounding circuit disables the integrating function for large errors when rapid corrective action is desired. The memory action of integrating Capacitor C19 causes the controller to be sluggish in such transient operations. The method of disabling the capacitor depends upon the sign of the error and the polarity of the voltage across C19.

When the sensor voltage (V_S) is smaller than the set point voltage (V_{sp}), the error signal $V_\varepsilon = V_S - V_{sp} < 0$ and an over-temperature condition exists. The input voltage ($-V_o$) to the reset amplifier is also negative resulting in an output voltage which would integrate towards a large positive value. To avoid this condition, since reset is not required, the diode CR6 essentially shorts the output to ground.

If, however, the sensor voltage is larger than the set point voltage (V_{sp}), the error signal is positive and an under-temperature condition exists. If the input voltage ($-V_o$) = $|Av1|V\varepsilon < 2$ volts, then the output voltage of the comparator (U11) is -15 volts. The integrator is therefore disabled since the diode CR5 is contrasting with its anode close to -14 volts.

For an input signal ($-V_o$) between zero and two volts, the integrator is operational and ultimately, once the system is controlling and stable, the voltage developed across C19 becomes just equal to the error voltage (V_o) which is required to hold a constant temperature under open loop conditions. Since this voltage is now present on the capacitor of the reset amplifier, it is no longer needed at the output of the gain summing amplifier resulting in the error signal reducing to zero.

The switch in series with R77 in the feedback loop is closed when the AUTO RESET control is in the off position and the amplifier gain is approximately .001.

(h) Automatic Rate Circuit

For most cryogenic applications, the addition of rate will not greatly enhance the system response. However, in some applications, rate will improve response. The simplified circuit and transfer function are shown in Figure 4.4. Note that an output is only present for a rapidly changing input signal, and that the time constant varies from 1.85 to 187 seconds.

With the AUTO RATE switch closed, the circuit is effectively disabled from the controller since the gain is less than 10^{-3}.

(i) Output Power Amplifier

The output power stage consists of a summing amplifier and two stages of voltage amplification, an output switching network and a variable supply voltage.

First note that on the one ampere scale the supply voltage is 25 volts while on all other maximum current ranges the supply voltage is approximately 7.5 volts.

The voltage at the input of U12 is $V_I = \varepsilon + \int \varepsilon\, dt + d\varepsilon/dt$. The overall gain of the summing amplifier is broken up into settings. Since R39 = R56 = R55 = 20K, the gain for the 1 ampere setting is

$-\frac{(R79 + R58)}{20K} \cong -12$. The gain for the other four settings is

$-R58/20K \cong -5$.

(j) Manual Heater Control

When the mode selector switch is set to either MAN A or MAN B position, switch section S1E connects the input of the power amplifier stage to the wiper of potentiometer R57 through resistor R74. Varying the wiper position from zero to its maximum will vary the output voltage at the emitter of Q1 from 0 to 25 volts on the 1 ampere scale and from 0 to 7.5 volts for all other current selectors. The heater element current is thus varied proportionally to the setting of R57 and the maximum heater current switch (S4) position.

(k) Heater Current Metering and Limiting

The heater element current is measured by the heater current ammeter, shunted by resistor R65 through R69 as appropriate for the current range selected. The full scale output current is determined by the series combination of the heater element resistance and one of the group of resistors R70 through R72. This series combination is connected across the nominal 7.5 or 25 volt output of the power amplifier. Approximately .5 volts appears across the Heater Current Meter (M1) and its appropriate shunt resistor.

Under no circumstances shall the rating of fuse FU2 be increased above one ampere in an attempt to achieve a power dissipation of 25 watts in a heater element whose resistance is less than 25 ohms. Such a substitution invalidates the instrument warranty and is likely to damage the output power amplifier circuit.

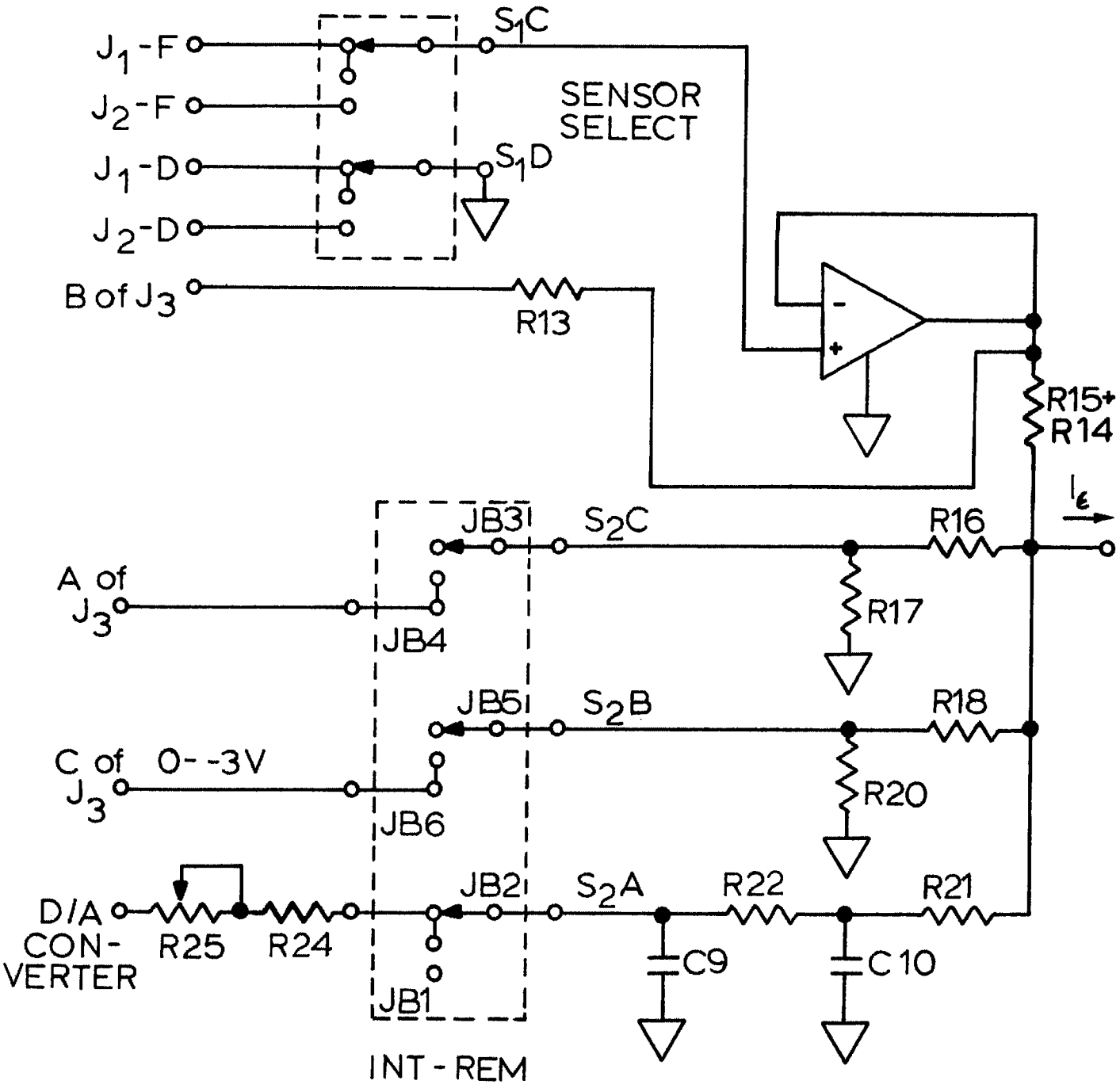
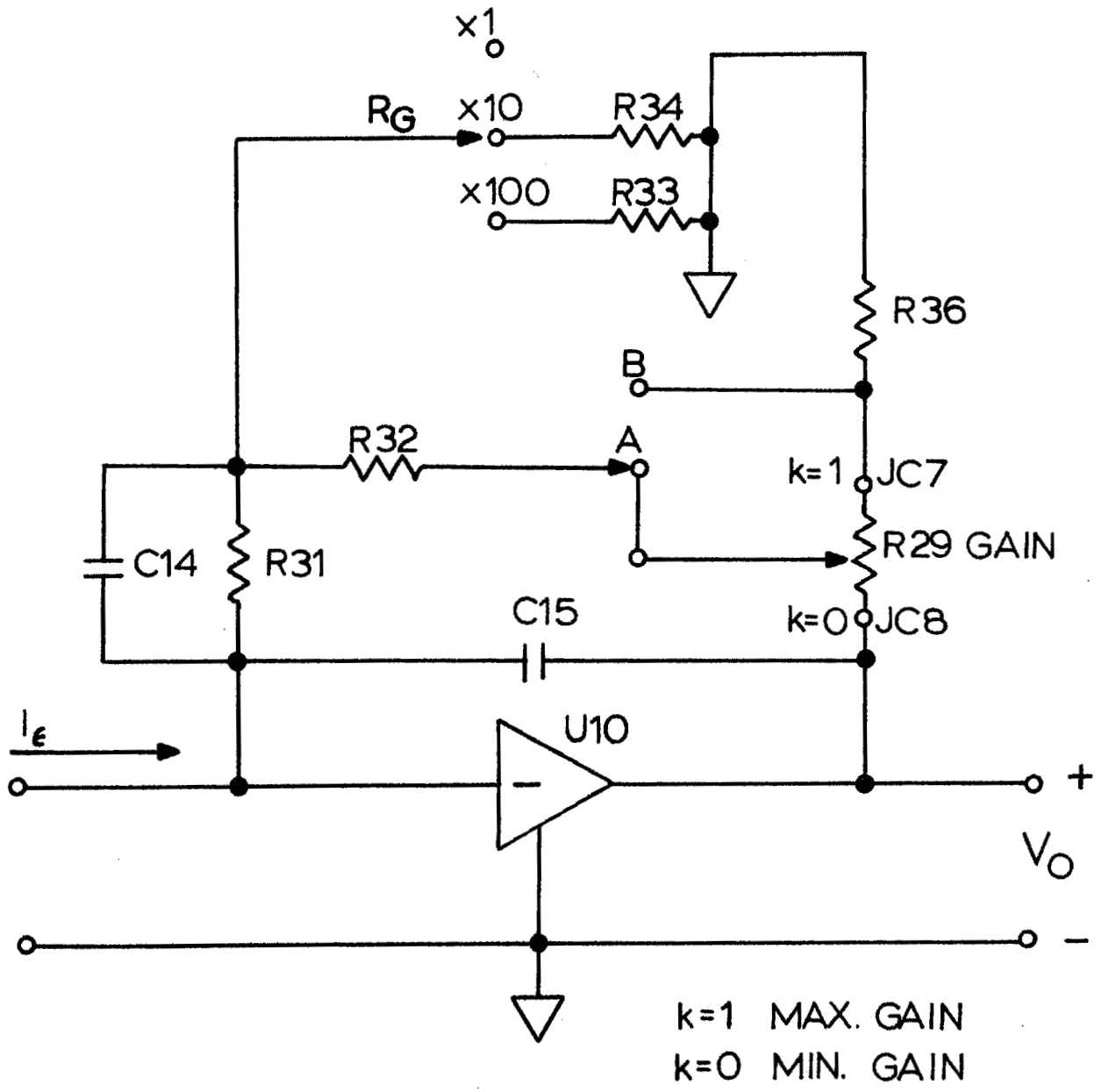
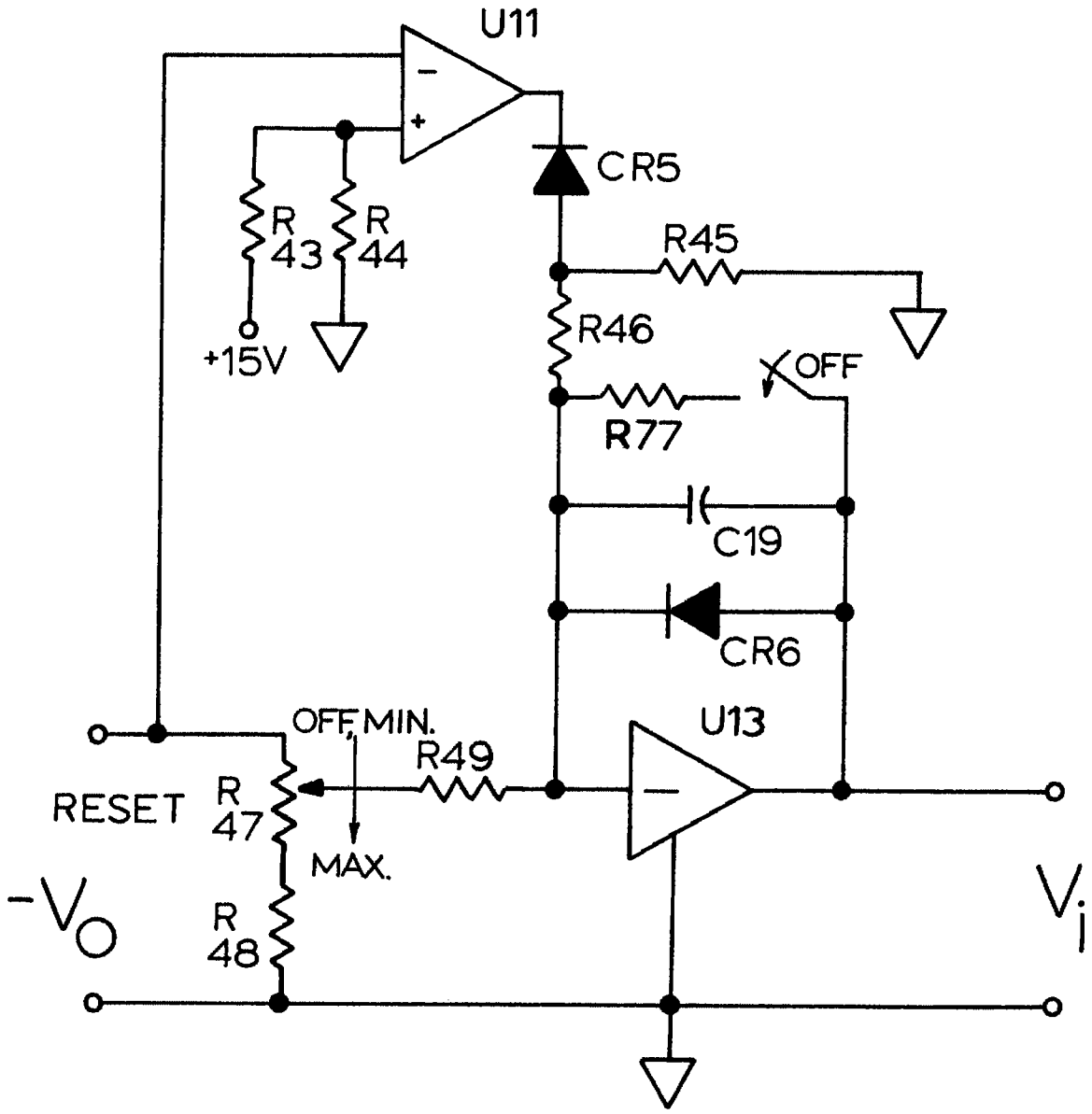


Figure 4.1 Internal/Remote Circuitry Indicating Switching and Summing of Input Signals



$$\frac{V_O}{V_\epsilon} = \frac{V_O}{i_\epsilon R_{15}} = \frac{-1}{R_{15}} \left[k R_{29} \left(1 + \frac{R_{31}}{R_G}\right) + \frac{\left(1 + \frac{R_{36}}{R_{29}}\right)\left(R_{32} + R_{31} + \frac{R_{32}R_{31}}{R_G}\right)}{1 - k + \frac{R_{36}}{R_{29}}} \right]$$

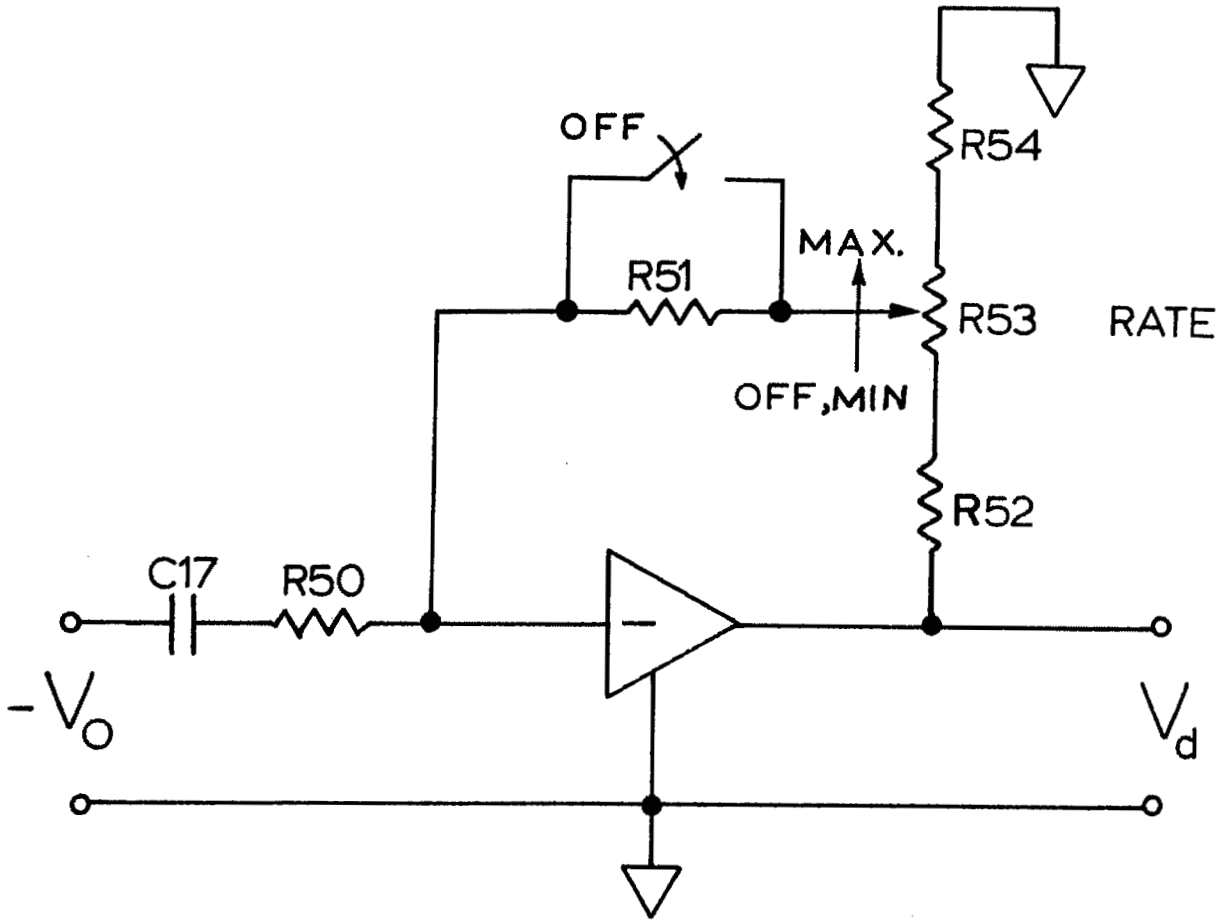
Figure 4.2 Simplified Equivalent Circuit and Transfer Function of Gain Summing Amplifier



$$\frac{V_i}{-V_o} = \frac{-1}{\left[1+kR_{47}\left(\frac{1}{R_{49}}+\frac{1}{R_{48}+(1-k)R_{47}}\right)\right]SR_{49}C_{19}}$$

RESET SWITCH	τ, SEC.	
OFF	–	$\left(\frac{V_i}{-V_o}=-0.0014\right)$
MIN (k=0)	1.43	
MAX. (k=1)	145	

Figure 4.3 Simplified Equivalent Circuit of Automatic Reset Amplifier



$$\frac{V_d}{-V_o} = -\left[1+(R_{52}+k\,R_{53})\left(\frac{1}{R_{51}}+\frac{1}{R_{54}+(1-k)R_{53}}\right)\right]\frac{sR_{51}C_{17}}{1+sR_{50}C_{17}}$$

RATE SWITCH	τ, SEC.
OFF	$.22\times 10^{-3}$
MIN (k=0)	1.85
MAX (k=1)	187

Figure 4.4 Simplified Equivalent Circuit of Automatic Rate Amplifier

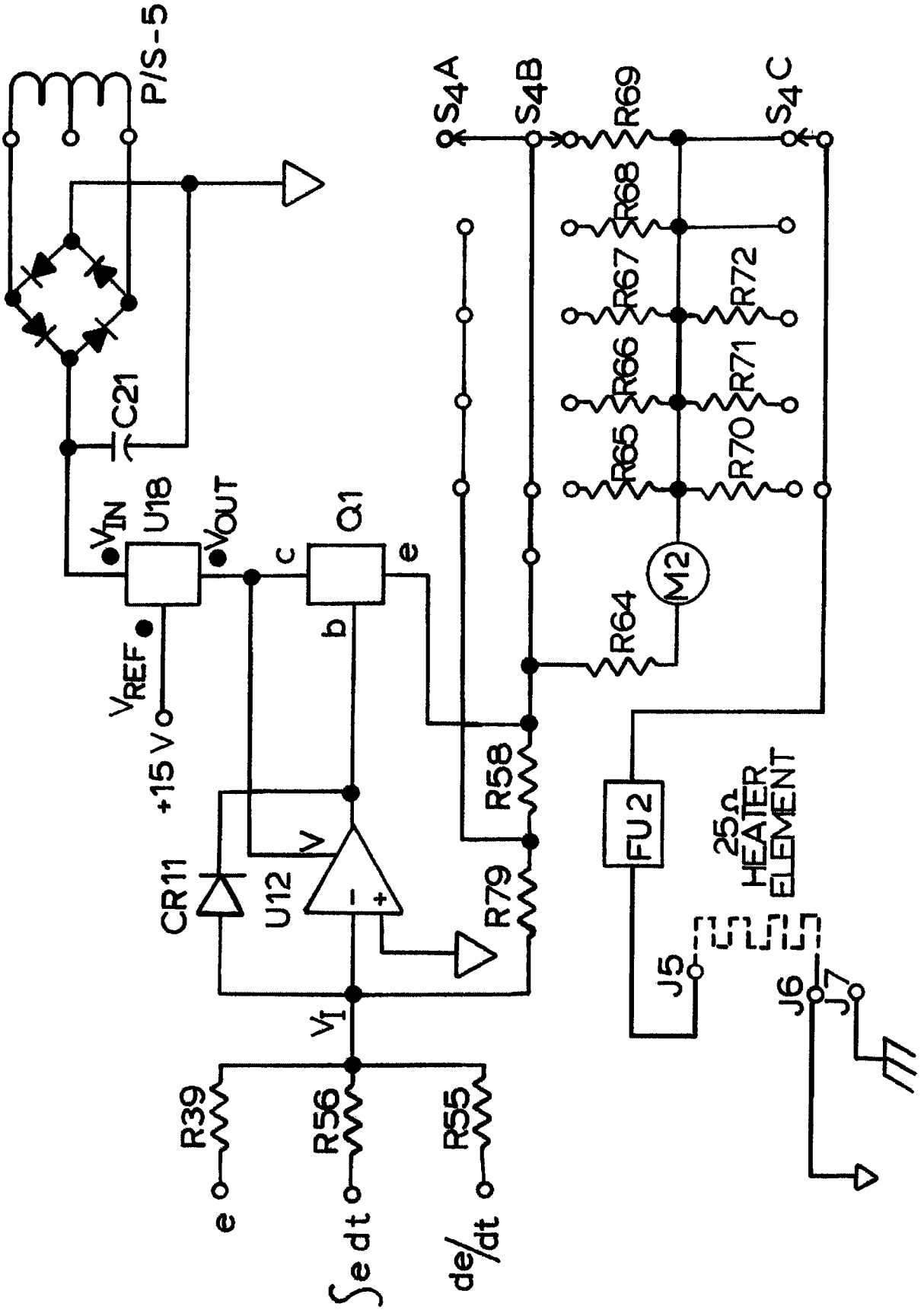


Figure 4.5 Circuit Schematic for Power Stage Showing Switching of Full Scale Current

SECTION V

Maintenance and Troubleshooting

5.1 Introduction

This section contains instructions for maintaining and calibrating the controller, nominal voltage values and gains, circuit schematic diagram, printed circuit board component diagram and parts list.

5.2 Test Equipment and Accessories

An RCA Senior Voltohmyst vacuum tube voltmeter or an equivalent high input impedance digital voltmeter; a 25 ohm, 25 watt resistor to simulate the heater element; and a precision resistor connected to simulate the diode in a connector assembly wired according to Fig. 2.1 (c) are normally sufficient for testing and calibrating the DTC-500A Controller.

5.3 General Remarks

Upon initial installation, the single most probable cause of system malfunction is an improperly connected temperature sensing diode. If it is impossible to zero the null meter at any setting of the set point voltage controls, carefully examine the cable/diode assembly to insure that the diode polarity is correct, that the sensor is plugged into the "SENSOR A" receptacle and that the "SET POINT SELECTOR" switch is in the INTERNAL position.

Because of the highly reliable solid state design of the controller, it is most unlikely that the controller will be a source of difficulty. For this reason, it is advisable to examine other portions of the cryogenic system before testing the controller proper. Some suggested checks are:

A. Open or shorted sensor and heater leads, particularly in the vicinity of the sample holder if it is subject to frequent dis-assembly.

B. Leakage paths between heater and sensor leads giving rise to electrical feedback in addition to thermal feedback.

C. Premature loss of cryogenic fluid due to thermal shorts in dewar, ice blocks in lines, sample holder immersed in cryogen, sample holder in vapor whose temperature is above the controller set point temperature, etc.

D. Excessive thermal path phase lags will cause the control loop to be unstable at high gain settings. Physical separation between the diode and heater, particularly by paths of small thermal cross-section should be avoided.

E. Examine heater element fuse FU2.

If it is indicated that the controller is malfunctioning after performing the tests to be described below, it is recommended that the instrument be returned to the factory for repair. The components used in the instrument are costly and may be permanently damaged if subjected to inappropriate test voltages or excessive soldering iron heat. Although premium materials and techniques have been used to

fabricate the instrument circuit board, there is always the risk of lifting a connection pad or cracking the board when unsoldering a component.

5.4 Servicing Printed Circuit Boards

It is suggested that components be unsoldered for trouble shooting only as a last resort since ample information is available at the numbered terminal pins. Attempt to infer component currents by voltage tests rather than removing a lead and seriesing it with an ammeter. All voltages are available for measurement from the top side of the printed circuit board. When it is necessary to replace a component, access is available by removing the bottom cover.

Use a low heat (25 to 50 watts) small-tip, freshly tinned soldering iron. Use small diameter, rosin core solder. Remove a component lead by applying heat to the lead, observing the solder melt and then pulling the lead through the board from the top side. Never apply tension to printed wiring from the bottom side.

Thoroughly clean all of the old solder from the mounting hole before inserting a new component with the use of a wick or desoldering suction device. Shape the new component and insert in mounting hole. Do not use heat or force to insert the new component. If the leads will not go through the hole, file the lead or clean the hole more thoroughly. Once mounted properly, apply heat to lead and wiring pad simultaneously and resolder. Clean excess flux from the connection and adjoining area with warm water and weak detergent if need be. (Contamination in some areas of the board can seriously degrade the high input impedance of the operational amplifiers.)

5.5 Operational Checks

Replace the sensor diode connector plug with a test plug made up according to Fig. 2.1 (c). Substitute a precision resistor for the sensor diode in the test plug. Remove the heater element leads and place a twenty-five watt, twenty-five ohm resistor across the heater output terminals.

Ten microamperes flowing through the test resistor should develop a potential of 1.00 volts across a 100 K ohm resistor. With the gain set a maximum position and the mode selector switch in position MAN. A (assuming the test plug is in SENSOR A receptacle), attempt to null the error with a set point voltage in the vicinity of 1.0 volts. The null meter should swing smoothly as the set point voltage is varied in the vicinity of the null.

While still in the MAN. A position, set the HTR CURRENT RANGE switch at 1000. Vary the MANUAL SET potentiometer from zero toward its maximum. The current meter should increase linearly along with the advance of the MANUAL SET control. With the MANUAL SET control set to give mid-scale heater current meter deflection, rotate the MTR CURRENT RANGE switch though all of its positions. The heater current meter indication should remain approximately at mid-scale in all of the positions.

Zero the null meter with the set point voltage controls. Turn the AUTO RESET and GAIN controls to mid-scale position. Set the HTR CURRENT RANGE switch to 1000. Position the mode control switch to AUTO A. Abruptly change the set

point voltage sufficiently to cause a +10 unit deflection of the NULL meter to the right. The heater current meter deflection will consist of two components. The first is a rapid step rise due to the steady null error and a second, gradually rising component due to the AUTO RESET circuit integrating the steady error. The heater current meter will gradually rise toward full scale deflection. The rate at which the heater current rises is determined by the AUTO RESET time constant setting. The rate is a minimum in the counterclockwise position and a maximum in the fully clockwise position.

Abruptly change the set point voltage to cause -10 units deflection of the NULL meter to the left. The HEATER CURRENT meter should gradually decrease from full scale deflection to zero. The rate at which the current meter goes to zero is in part determined by the bounding circuit. Its non-linear behavior accounts for the assymetry in the temperature versus time characteristics as shown in Figure 3.4.

If the instrument responds to the tests outlined above as indicated, either the trouble lies elsewhere in the system or the malfunction in the controller is of a subtle nature.

5.6 Calibration of Sensor Current

The sensor current has been factory calibrated to 10 microamperes ±10 nanoamperes. To check the sensor current without removing the case cover, a conveniently available precision resistance of not less than .01% tolerance should be connected to pins A-B of the sensor connector socket (J_1 or J_2), and the sensor selector switch on the front panel switched to the appropriate sensor input (A or B). The "SET POINT SELECTOR" switch should be switched to "REMOTE", and remote plug (J3) be disconnected.

A high quality potentiometric voltmeter connected to the precision resistor should measure a voltage equal to 10 microamperes times the value of the resistor. Typically, a 100 K ±.01% resistor should read 1.0000 within 100 microvolts. If recalibration is indicated, the voltage across the precision resistors can be recalibrated after removing the case cover and adjusting trimmer R5 on the circuit board.

Note that due to the non-linearity of the diode, the adjustment of the current source does not have to be to the same level of accuracy as the measurement of voltage across the sensor.

5.7 Zero Offset of Input Buffer Amplifier

This amplifier has been trimmed at the factory and should not require immediate attention. After a few months of operation, it may introduce some measurement error due to a zero offset. For example a 1mV zero offset in the output would correspond to approximately a 0.4 K offset in the sensor reading above 30K where the sensitivity is approximately 2.5mV/K. Below 25 K where the sensitivity is approximately 50mV/K, this would result in an appreciably smaller error.

This offset may be zeroed as indicated below:

A. Allow 20 minutes for warm up of the controller.

B. Make a shorting plug so that Pins E and D, the sensor input voltage leads to the buffer amplifier are shorted. Place this shorting plug in J1.

C. Mode switch (Key No. 4) to "MAN. A".

D. Use a HIGH input impedance voltmeter to monitor output of buffer amplifier. The ground connection is Pin D of J1. The output connection is pin 6 of U9.

E. Adjust trim R10 so that the amplifier offset is less than ±100μV.

5.8 Zero Offset of Summing Amplifier

This amplifier has also been trimmed at the factory and should not require immediate attention. In order to zero the offset of this amplifier, it is necessary to first zero the offset of the input buffer amplifier (Section 5.7). With the shorting plug in place (J1) and no other inputs to the summing amplifier, i.e., no inputs to J3 or J4, set the digital set point to 0.0000 volts. Adjust the trim potentiometer R27 so that the null meter (Key No. 11) is at zero with the gain (Keys No. 2 and 3) at its highest value. Both amplifiers are now in balance with zero offset.

5.9 Adjustment of the Digital Set Point

The adjustment of the digital set point requires only a precision resistor in the range from 50 K to 250 K. Let us assume that the resistor has the value 100,010 ohms.

A. Complete sections 5.6-5.8.

B. Place the precision resistor in place of J1 using the connection diagram shown in Figure 2.1 (c).

C. Set the digital set point (Key No. 1) to 1.0001 volts.

D. Adjust trim potentiometer R25 so that the null meter reads zero with the gain (Keys No. 2 and 3) to its highest value.

The re-calibration of your controller is now complete.

5.9 Parts List, Component Location Diagram and Schematic

Table 5.1
PARTS LIST FOR DTC-500A

REF. DESG.	DESCRIPTION			LAKE SHORE PART NO.
R1	3.92K	¼W	1%	
R2	19.1K	¼W	1%	
R3	511 ohm	1/8W	1%	
R4	3.83K	1/8W	1%	
R5	10K Trim Pot (constant current adjust)			
R6	10K	¼W	0.5%	
R7	499K	¼W	1%	
R8	3.83K	¼W	1%	
R9	Not present			
R10	100K Trim Pot (Buffer - Zero)			
R11	Not present			
R12	Not present			
R13	1.0K	¼W	1%	
R14	100K	¼W	1%	
R15	909K	¼W	.1%	
R16	1 M	¼W	.1%	
R17	10K	¼W	.1%	
R18	1 M	¼W	.1%	
R19	Not present			
R20	100K	¼W	1%	
R21	423K	¼W	1%	
R22	423K	¼W	1%	
R23	423K	¼W	1%	
R24	154K	½W	.1%	
R25	20K Trim Pot (D/A Converter Adjust)			
R26	Not present			
R27	100K Trim Pot (Summer - Zero)			
R28	Not present			
R29	10K Pot (Gain Control)			
R30	8.25K	¼W	5%	
R31	1.96 M	¼W	.1%	
R32	100K	¼W	1%	
R33	1K	1/8W	1%	
R34	10K	¼W	0.5%	
R35	Not present			
R36	1.0K	¼W	1%	
R37	1.0K	¼W	1%	
R38	3.92K	1/8W	1%	
R39	20K	½W	1%	
R40	2.8K	¼W	.5%	

REF. DESG.	DESCRIPTION			LAKE SHORE PART NO.
R41	2.8K	¼W	.5%	
R42	1K	¼W	1%	
R43	14.7K	¼W	1%	
R44	2.0K	¼W	1%	
R45	10K	¼W	.5%	
R46	1.96 M	¼W	1%	
R47	100K Pot (Reset Control)			
R48	8.06K	¼W	1%	
R49	1.27 M	¼W	1%	
R50	1.96 M	¼W	1%	
R51	10 M	¼W	10%	
R52	866 ohm	¼W	1%	
R53	100K Pot (Rate Control)			
R54	866 ohm	¼W	1%	
R55	200K	¼W	1%	
R56	100K	¼W	1%	
R57	10K Pot (Manual Reset Control)			
R58	82.5K	¼W	1%	
R59	Not present			
R60	Not present			
R61	Not present			
R62	Not present			
R63	Not present			
R64	422 ohm	1W		
R65	54.9 ohm	1W		
R66	16.9 ohm	1W		
R67	4.97 ohm	1W		
R68	1.64 ohm	1W		
R69	.498 ohm	1W		
R70	715 ohm	1W		
R71	360 ohm	1W		
R72	81.6 ohm	1W		
R73	62 ohm	¼W	1%	
R74	1.5KM	¼W	20%	
R75	Not present			
R76	150K	¼W	1%	
R77	100 ohm	¼W	1%	
R78	1470 ohm	¼W	1%	
R79	174K	¼W	1%	
R80	2150 ohm	¼W	1%	
C1	.33 MFD, 25V, Mylar			
C2	150 PFD, 10V, Dipped Mylar			
C3	Not present			
C4	2.2 MFD, 35V, Metal Tantalum			
C5	Not present			
C6	.1 MFD, 100V, Mylar			

REF. DESG.	DESCRIPTION	LAKE SHORE PART NO.
C7	Not present	
C8	.33 MFD, 100V, Electrolytic	
C9	.33 MFD, 100V, Electrolytic	
C10	.33 MFD, 100V, Electrolytic	
C11	.33 MFD, 100V, Electrolytic	
C12	Not present	
C13	Not present	
C14	.022 MFD, 50V, Mylar	
C15	150 PFD, 50V, Dipped Mylar	
C16	.047 MFD, 50V, Tantalum	
C17	1.0 MFD, 100V, Electrolytic	
C18	0.1 MFD, 100V, Mylar	
C19	1.0 MFD, 100V, Electrolytic	
C20	.1 MFD, 100V, Mylar	
C21	2600 MFD, 50V, Electrolytic	
C22	2200 MFD, 16V, Electrolytic	
C23	470 MFD, 25V, Electrolytic	
C24	470 MFD, 25V, Electrolytic	
C25	470 MFD, 25V, Electrolytic	
C26	.1 MFD, 100V, Mylar	
C27	.1 MFD, 100V, Mylar	
C28	470 MFD, 25V, Electrolytic	
C29	1.0 MFD, 100V, Electrolytic	
C30	Not present	
C31	50 PFD, 5% Dipped Mylar	
C32	.0015 MFD, 5% Electrolytic	
U1	Presettable up/down Binary Decade Counter	CD4029 AE
U2	Presettable up/down Binary/Decade Counter	CD4029 AE
U3	Presettable up/down Binary/Decade Counter	CD4029 AE
U4	Presettable up/down Binary/Decade Counter	CD4029 AE
U5	Presettable up/down Binary/Decade Counter	CD4029 AE
U7	Dual D Edge Triggered Flip-Flop	MC1413 AL
U6	Quad 2 Input NAND Schmitt Trigger	CD4093 BE
U8	Dual SPDT Low Resistance Switch	AD7512 D1
U9	Operational Amplifier	OP15
U10	Operational Amplifier	OP15
U11	Dual Operational Amplifiers	MC1458P
U12	Operational Amplifier	F741TC
U13	Operational Amplifier	LF356N
U14	Operational Amplifier	LF356N
U15	Positive Voltage Regulator (1.5A)	MC7805
U16	Negative Voltage Regulator (1.5A)	MC7915
U17	Positive Voltage Regulator (1.5A)	MC7815
U18	Positive Voltage Regulator (1.5A)	MC7815
U19	Operational Amplifier	LN308
U20	Voltage Reference	LM399H

REF. DESG.	DESCRIPTION	LAKE SHORE PART NO.
U21	F.E.T.	3N163
U22	Not present	
U23	Voltage Reference	LM399H
Q1	Power Transistor	2N6044
J1	5 pin sensor socket, Amphenol	
J2	5 pin sensor socket, Amphenol	
J3	7 pin remote set point, Amphenol	
J4	40 pin connector	
J5	Heater Binding Post	
J6	Heater Binding Post	
J7	Chassis Ground Post	
J1[1]	Internal Wiring Header	
J2[1]	Internal Wiring Header	
F1	Fuse Holder, Littlefuse	
F2	Fuse Holder, Littlefuse	
CR1	Silicon Diodes	
CR2	Silicon Diodes	
CR3	6.2V Zener Diode (Semcor LMZ6.2)	
CR4	6.2V Zener Diode (Semcor LMZ6.2)	
CR5	Silicon Diode	
CR6	Silicon Diode	1N459
CR7	Silicon Diode Bridge	WL005
CR8	Silicon Diode Bridge	WL005
CR9	Silicon Diode Bridge	W102M
CR10	Silicon Diode Bridge	W06M

Table 5.1

PARTS LIST FOR DTC-500A

BCD I/O Option

REF. DESG.	DESCRIPTION	LAKE SHORE PART NO.
U1	Level Translator TTL to Logic High MOS	F4104 BPC
U2	Level Translator TTL to Logic High MOS	F4104 BPC
U3	Level Translator TTL to Logic High MOS	F4104 BPC
U4	Level Translator TTL to Logic High MOS	F4104 BPC
U5	Level Translator TTL to Logic High MOS	F4104 BPC
U6	Quad AND -OR Select Gate	SIL 4019 BC
U7	Quad AND-OR Select GATE	SIL 4019 BC
U8	Quad AND-OR Select Gate	SIL 4019 BC
U9	Quad AND-OR Select Gate	SIL 4019 BC
U10	Quad AND-Or Select Gate	SIL 4019 BC
U11	Quadruple D-Type Flip-Flops	74LS175N
U12	Quadruple D-Type Flip-Flops	74LS175N
U13	Quadruple D-Type Flip-Flops	74LS175N
U14	Quadruple D-Type Flip-Flops	74LS175N
U15	Quadruple D-Type Flip-Flops	74LS175N
U16	Hex Buffers/Drivers with open-collector High-Voltage Outputs	D53630N
U17	Hex Inverter	MM 74C14N
U18, 19	Quadruple 2-Input Positive And Gates	74LS08N
U20	Interface - Analog to Digital Converter	ICL 7103 ACPI
U21	Interface - Analog to Digital Converter	ICL 8052 ACPD
R101	866 1/8w 1%	
R102	100K 1/8w 1%	
R103	100K 1/8w 1%	
R104	300K ¼w 1%	
R105	35.7K ¼w 1%	
R106	100K Trim pot	
R107	549Ω ¼w 1%	
R108	100K 1/8w 1%	
R109	Not Present	
R110	14K ¼w 1%	
R112	182Ω 1/8w 1%	
C101	0.1 MFD, 100V, Mylar	
C102	.68 MFD, 100V, Mylar	
C103	Not present	
C104	300 PFD	
C105	.22 MFD, 100V, Polypropylene	
C106	.68 MFD, 100V, Mylar	
C107	Not present	
C108	360 MFD	

REF. DESG.	DESCRIPTION	LAKE SHORE PART NO.
C109	.1 MFD, 100V, Mylar	
C110	.1 MFD, 100V, Mylar	
C111	.1 MFD, 100V, Mylar	
C112	2.2 MFD, 35V, Tantalum	
C113	2.2 MFD, 35V, Tantalum	
CR101	Diodes 1.5 V IN125	
CR102	Diodes 1.5 V IN125	

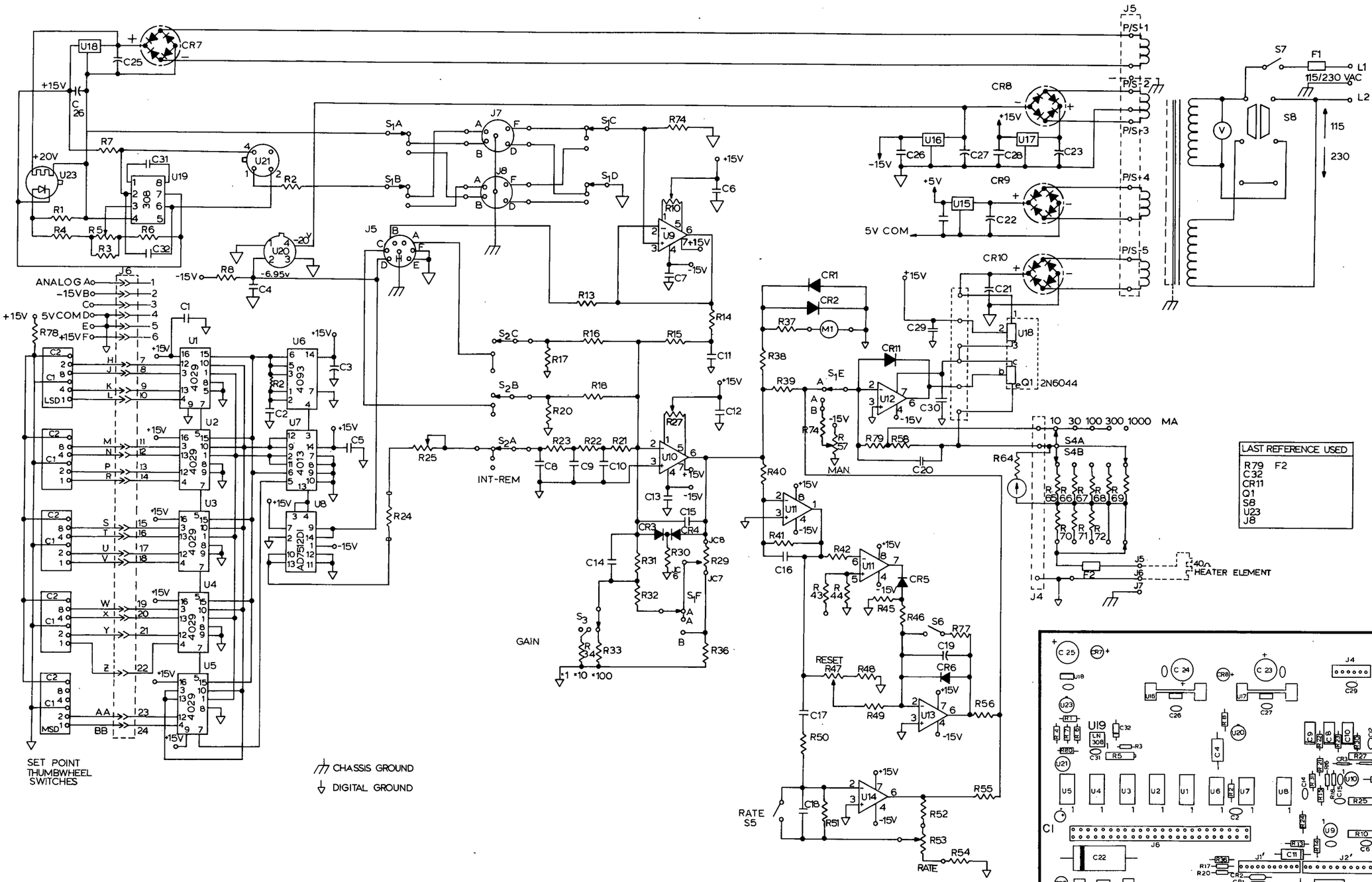
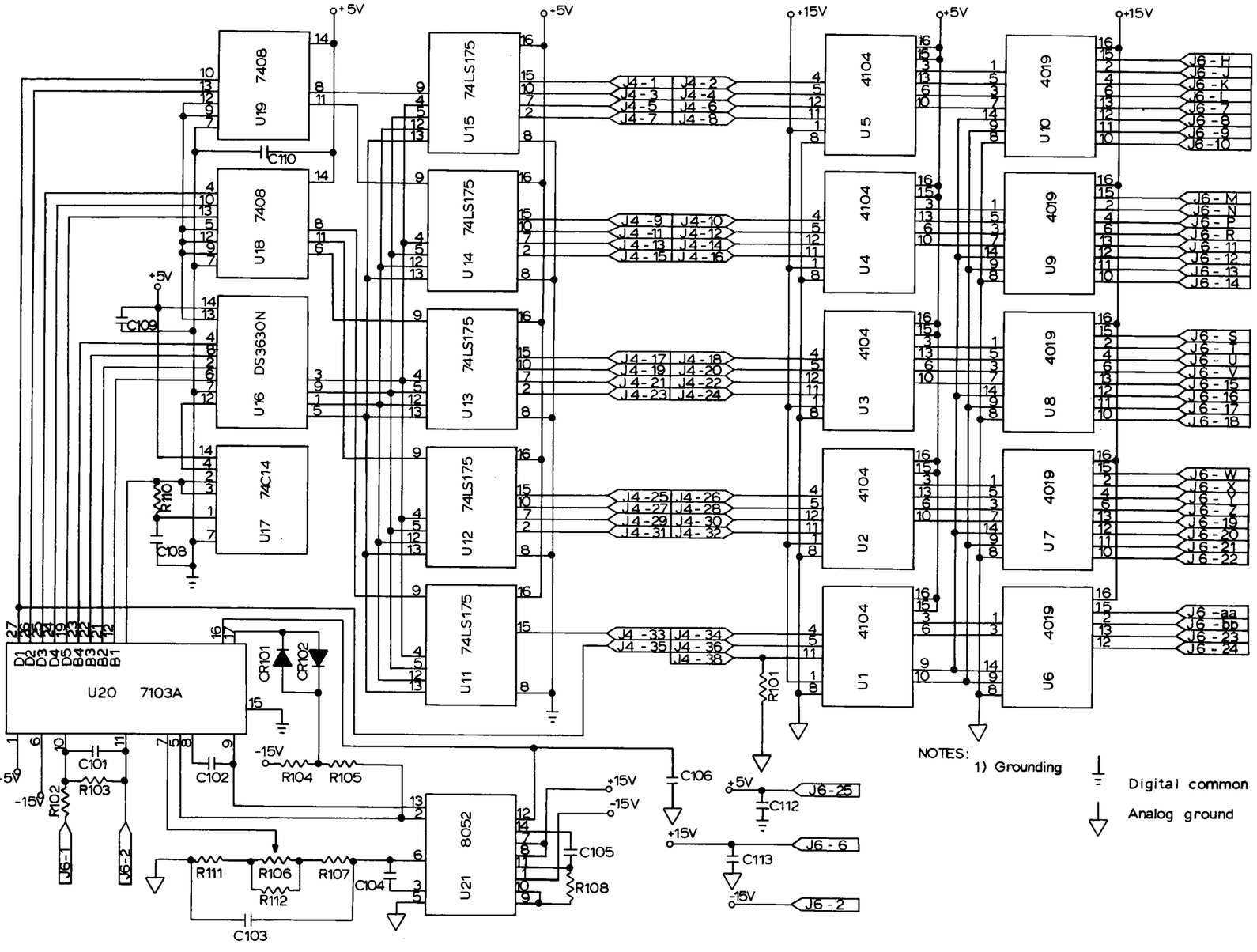


Figure 5.1 Circuit Schematic Diagram

Figure 5.2 Parts Layout for Printed Circuit Board



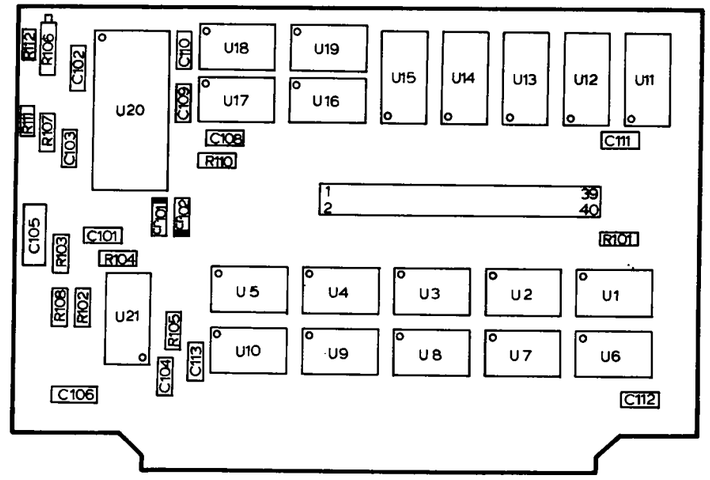


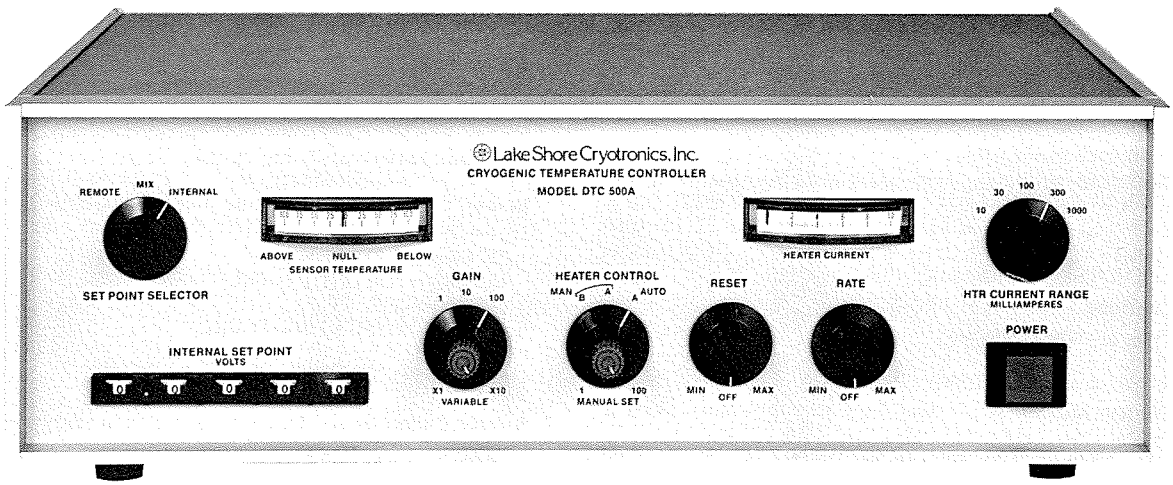
Figure 5.3 Circuit Schematic Diagram for BCD In/Out Option

Figure 5.4 Circuit Board Component Diagram for BCD In/Out Option

Lake Shore Cryotronics, Inc.
64 E. Walnut St., Westerville, Ohio 43081
(614) 891-2243 • Telex: 24-5415 • Cryotron WTVL

Technical Data
DTC-500A
Temperature Controller

Versatile, Precision Thermometer/Controller Provides Ultra-Stable Cryogenic Temperature Control.



Features:

- **1.4 to 380K Range**
- **True Three-Mode Control**
- **Uses Silicon-Diode Sensors**
- **100 μV Set Point Resolution**
- **Manual Heater Override**
- **Controllability to ±0.5mK Below 28K**
- **0-25 Watt Heater Output**
- **Optional BCD Interface**

The Lake Shore Cryotronics Model DTC-500A is the top-of-the-line Temperature Controller for use with all DT-500 Series Silicon Diode Temperature Sensors. True three-mode control (gain, rate, and reset) is combined with premium-spec components to allow system control as stable as ±0.5 millikelvin below 28K and ±5mK at higher temperatures.

The DTC-500A utilizes any Lake Shore DT-500 Series silicon diode Sensor (calibrated Sensors are recommended for optimum accuracy and versatility). A built-in 10-microampere source provides the Sensor excitation current. The voltage signal from the Sensor is then compared to the set-point and the error signal is amplified to provide the heater drive. Use of analog control means constant and immediate correction for temperature changes. Ample range of gain, reset, and rate have been designed into the 500A to assure fast response, low offset error, and high stability.

Because the set-point is in voltage rather than temperature, the controller is easily able to accommodate sensors with various response curves as well as externally generated set-points without the accuracy constraints imposed by standard-curve systems. The set-point is settable from 0.0000 to 2.9999 volts via either front panel thumbwheels, external analog voltage or resistance control, or digitally with the optional DTC-BCD Interface which also provides a BCD output of the sensor voltage (÷2).

Accurate temperature measurement is also possible with the DTC-500A by operating the unit in the open-loop mode. The sensor voltage is nulled against the set-point using the built-in meter, thus the set-point becomes a read-out of the actual sensor voltage. Referral to a V vs T calibration table for the particular sensor yields the actual temperature reading. A dual-sensor input is provided on the 500A which enables redundant measurements or optimization of sensor location for best control and most accurate readout.

Heater output of up to 25 watts is available from the DTC-500A. Maximum heater current may be set from 10mA to 1A in 1X and 3X steps. This enables output power to be appropriately limited to protect delicate heaters or systems as required.

Multi-sensor inputs for the DTC-500A are possible with the accessory Model SW-10A Sensor Selector. Up to 10 sensors can be connected to either of the dual inputs on the DTC-500A. Selection is made via front-panel pushbuttons on the SW-10A.

For the ultimate in stability and versatility in cryogenic temperature measurement and control, turn to the Lake Shore Cryotronics DTC-500A.

Specifications, DTC-500A Cryogenic Temperature Controller

Input:

Temperature Range: 1.4 to 380K with Lake Shore DT-500 Series Sensors (0 to 3.0 volts for other sensors).

Recommended Sensors: DT-500 Series Silicon Diode Sensors (order separately). Calibration required over appropriate temperature range to provide V vs T data.

Sensor Input: Dual-sensor input. 4-terminal input for each sensor. Can be connected in 2-wire configuration. Sensor A position is used for automatic control mode. Sensor A or B positions are used in manual mode for temperature readout or manual control.

Sensor Excitation: 10 microampere current source.

Temperature Control:

Set-Point: Internally selected via 5 front-panel digital thumbwheel switches from 0.0000 to 2.9999 volts. Externally selectable via either resistance (0 to 1000 ohms) or voltage (0 to -3 volts). Optional BCD control with DTC-BCD Interface.

Set-Point Resolution: 100μV.

Typical Controllability: ±0.0005K for temperatures from 1.4 to 28K, ±0.005K at higher temperatures in a properly designed system.

Control Modes: Automatic: Proportional (gain), integral (reset), and derivative (rate). Set from front panel controls. Manual: 0 to 100% of full output can be set from front panel.

Heater Output: 0-25 watts into 25 ohm load. Heater current range can be limited at 10mA, 30mA, 100mA, 300mA, and 1A (approximate decade power increments).

Temperature Readout:

Method: Sensor voltage is nulled against set-point voltage using front-panel thumbwheels in MANUAL mode. Temperature is determined from V vs. T tables (requires sensor calibrated over appropriate temperature range).

Accuracy: ±100 microvolts ±calibration error of Sensor.

General:

Remote Set-point Input: 7-pin rear panel connector or optional BCD interface connector.

Dimensions, Weight: 432mm wide x 146mm high x 330mm deep (17 in x 5¾ in x 13 in). Style L, full-rack package. Net weight 8.2 kg (18 lbs).

Power: 105-125 or 210-250 VAC (switch selected), 50 or 60Hz, 65 watts.

Accessories Supplied: Mating connectors for sensor and remote inputs, instruction manual.

Options and Accessories Available:

Model DTC-BCD Interface. Allows remote digital control of set-point and provides BCD output of Sensor voltage divided by two.

Model SW-10A. 10-Sensor Selector Switch. Pushbutton selection of any one of up to 10 sensors. Dimensions: 216mm wide x 102mm high x 330mm deep (8½ in x 4 x 13 in). Style L half-rack package .

Model RM-3H. Rack mount kit to mount either one or two SW-10A in standard 3½" rack space .

Model RM-5F. Rack ears with handles to mount DTC-500A in standard 5¼" rack space .

Model DT-500 Silicon Diode Sensors. (Refer to Lake Shore Series DT-500 Technical Data for complete list).

DT-500K or DT-500KL
DT-500K-TO5 or DT-500KL-TO5
DT-500P-GR
DT-500P or DT-500P-GR MINI
DT-500FP
DT-500-CU-36

Sensor Calibrations. (Other ranges also available).

Type	Range-K
1.4B	1.4-40
1.4F	1.4-300
1.4G	1.4-380
4B	4.0-40
4F	4.0-300
4G	4.0-380

Expanded Calibration Printout. (Interpolated data at equal intervals over calibration range).

First 500 data points
Each additional 1000 data points

Lake Shore Cryotronics, Inc.
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